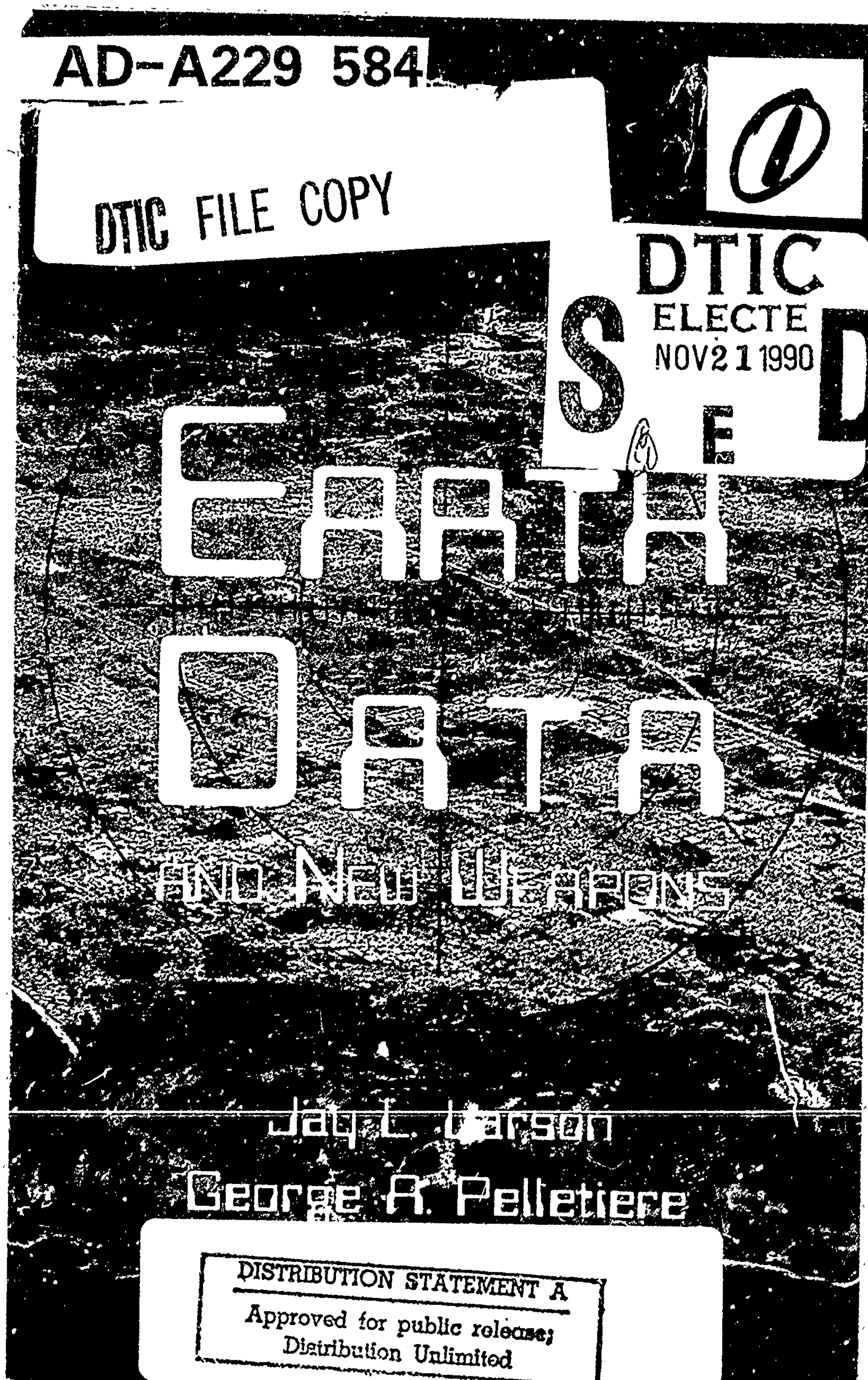
EARTH
DATA
AND NEW WEAPONS
Jay L. Larson
George A. Pelletiere

About the cover: The cover is a computer-generated image of the Los Angeles area. "Earth data"—quantified and codified information about the earth and its surface features—was used to produce the image and is a critical element in the use of many new weapons. *Courtesy of the Jet Propulsion Laboratory, California Institute of Technology, National Aeronautics and Space Administration.*

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JAY L. LARSON
AND
GEORGE A. PELLETIERE

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FOREWORD

weapons

Many modern aircraft, missiles, and artillery require detailed information about the earth to guide them to target. This "earth data" is also necessary for training those who will man the aircraft, launch the missiles, and fire the artillery. weapons. The authors believe

use single quotes

According to Jay Larson and George Pelletiere, however, inadequate data now mars the early, critical stages of weapons development and acquisition. In this challenging study, the authors catalog a history of bureaucratic omissions, contradictions, and funding disputes that have hampered earth data programs. Larson and Pelletiere recommend system improvements under the general aegis of the Department of Defense, with the Defense Mapping Agency taking a leading role. They suggest specific ways to clarify existing regulations, standardize earth data products, identify earth data requirements *early* in the weapons acquisition process, and adequately fund development. Keywords;

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Some will find this book controversial, but no responsible reader will find its argument less than coherent nor its revelations less than sobering. The authors' insights may well point the way for better use of new technology in the service of national security.

BRADLEY C. HOSMER
LIEUTENANT GENERAL, USAF
PRESIDENT, NDU

Guidance/data bases; Earth planet.
(EDC)

1. THE WORLD WE LIVE IN

Recent history has shown us that the Third World presents many of today's military challenges and threats. Libya, Iran, and Nicaragua are all examples of where the United States has had to consider making a highly accurate military response. No longer are US military targets restricted to the other superpower and a few well-known belligerent nations.

Where will the next crisis come from and how will we handle it? Part of the problem in planning a response comes from the fact that today a crisis can develop very rapidly. Defense planners may only have a few days to finalize the complex details of an operation. The US military response in Grenada serves to remind us of this fact.

International Crisis: A Fictional Scenario

Let us postulate an entirely fictitious scenario. The country is Indonesia. The scene is all too familiar. Anti-American sentiments rise. There are demonstrations. Rocks and several fire bombs are thrown at the US embassy in Jakarta. An American businessman is caught in one of the demonstrations and killed. Was he a chance victim, or was this mob specifically looking for

an American to mutilate and kill? Some evidence points to the latter.

Hostilities spread through the region. A series of well executed terrorist incidents on and around US military bases in the Philippines claim the lives of 15 American soldiers, 9 men and 6 women. Intelligence data indicates that the Indonesian Ministry of Defense is involved.

Before the United States can take diplomatic action, additional intelligence information catapults this situation into crisis status. Indonesia has secretly purchased sophisticated surface-to-air missiles from the Soviet Union and Silkworm missiles from the People's Republic of China and has deployed them along several straits and on various islands. Indonesia thus threatens shipping lanes from Malaysia to Australia but veils its position by announcing that it is merely expanding the South Pacific nuclear-free zone. The Minister of Defense proclaims that no warships armed with nuclear weapons will be permitted to pass through any of the key straits which Indonesia now dominates. Unofficially, the government lets it be known that they mean primarily US warships.

Let's pause a minute to examine the motive behind the fictitious Indonesian actions. Obviously they want to increase their influence in Southeast Asia. Perhaps the underlying motive is to give this far-flung, diverse country a cause for cohesion and regional influence. These are seen as necessary if Indonesia is going to join in the economic prosperity of its East Asian neighbors.

The crisis continues to develop. The United States decides that it must challenge Indonesia's right to control these strategic international waterways. A carrier battle group in the South China Sea is directed to transit the Strait of Malacca on its way to the Indian Ocean. The group assumes its highest defensive posture as it passes within range of the Silkworm missiles. As if on cue, the Indonesians fire two missiles at the US force. Both missiles are destroyed at a safe distance from the US ships. American technical superiority appears to have triumphed again. But, just as the battle group leaves the danger zone, a low-flying aircraft coming from the other side of the strait fires several missiles at one of the support ships. The support ship is hit and badly damaged. Fifty-three crew members are killed.

Indonesia claims that the United States provoked the incident by attacking the missile site and firing first. It further claims that the US ship was fired upon only in self-defense and was, in fact, hit by a Silkworm missile. The fact that none of this is true does not help the United States' situation. The damage is done; the United States is clearly in an untenable position and must take immediate action.

The White House gives the Joint Chiefs of Staff (JCS) two days to plan a response that can be executed in five days. JCS planners conclude that the response should consist of a two-pronged attack. One prong must be against the Silkworm sites along the Strait of Malacca. Navy fighter bombers from the carrier battle group that just transited the strait can avenge the death of the 53 sailors. The other prong of the attack is more

sensitive: the response must carry a clear political warning and be an effective military retaliation. The planners intend to do this by hitting the Ministry of Defense, a terrorist training center, and several other military targets in and around Jakarta. Civilian casualties must be minimized in this densely populated city. The ideal weapon, with adequate precision for this job, is the Navy's new multi-billion dollar conventional cruise missile.

The mission is approved as proposed. But there is a snag: the planners discover that cruise missiles cannot be used for this operation. Why? The missiles are available, but they need digital targeting data in order to function, data that takes several weeks to build.

Without the cruise missiles, the Jakarta phase of the operation is now handed over to the Air Force. The Air Force wants to fly this mission from Clark Air Force Base in the Philippines, but the Philippine government is too afraid of retaliation and refuses permission. The Air Force planners decide to use eight B–52s from Guam.

This mission has become enormously expensive in terms of forces committed. It takes tanker aircraft support for the B–52s as well as electronic warfare aircraft and combat air patrol aircraft to attack both locations. The Air Force is included in the mission because all naval aviation assets in the area are committed to the first prong of the attack and to support roles.

The mission takes place seven days after the fight in the Strait of Malacca. The Navy succeeds in doing major damage to the Silkworm site along the Strait of Malacca and escapes with no combat losses. The Air

Force also succeeds at hitting and damaging all assigned targets, but the Jakarta raid suffers from two big negatives. Collateral damage and civilian casualties are high. Jakarta, moreover, is extremely well defended, and two B–52s, with 12 crew members, are lost. Indonesia claims to hold 4 American airmen captive. One thing is clear, this raid did not go as well as it could have; the cruise missiles might have made a big difference.

What is the meaning of all this? We are certainly not suggesting that Indonesia will be the scene of the next international crisis. The scenario was purely fictional. A similar crisis could be invented for almost any country. Nor is this an indictment of the cruise missile. The *nuclear* cruise missile is fully capable of performing its mission. The *conventional* cruise missile is the most accurate weapon of its size and type in existence; it is capable of many important missions worldwide, and steps are being taken to correct the problems highlighted here.

This account was meant to introduce a problem worthy of attention. Even though the problem affects a surprisingly large number of new weapons and millions, maybe billions, of the taxpayers' dollars, it stems from only one aspect of the Department of Defense (DOD) system for developing new weapons. We are specifically addressing the area of digital earth data. Digital earth data can be loosely defined as the information about the earth needed for accurate positioning, targeting, and navigation. The information is stored on a medium such as magnetic tape or disk.

This book examines just how big this problem is

and how it can be fixed. We will explain in detail what earth data is, why it is so vital to our defense, why it is in short supply, and, most important, how the Department of Defense can solve this problem and save a great deal of money simply by restructuring a small part of its acquisition process.

The Problem

Let's explore in a little more detail the nature of the earth data problem. When and how did this problem arise? What are the broader implications of the problem? What can be done to remedy the situation? And who needs to understand and take action on the earth data issues?

The root of the problem is a general lack of understanding of earth data among those who research, develop, and acquire new weapon systems. This lack of understanding results in insufficient consideration of earth data throughout the development process, in engineering of systems which cannot be supported in a timely and efficient manner, and in inadequate or ill-advised DOD directives. The number and significance of the systems now in use and being designed which require earth data represent the very heart of US military strength in the Air Force, Navy, and the Army.

This is, in fact, a relatively new problem brought on by advances of technology. Recent progress in computers has made it possible to develop a host of new weapon systems with operational capabilities unheard of in the past. Many of these new systems require earth data in digital format. This burgeoning new technology has spread from the weapons themselves to battlefield management, intelligence analysis, and other support systems. The technology explosion and the United

States' commitment to qualitative superiority will make the issue of earth data support even more vital in the future.

A number of problems can follow a new weapon system that is designed and built without proper integration of earth data. Deployment of the system may be delayed; the earth data producers may be forced into an inefficient "crash" program to create the data; the system may be limited to a small geographic area for initial operation; or some combination of these situations may occur. The central element of the problem is timing: all of these problems can eventually be solved given enough time—and money.

We submit that these problems continue to recur for almost every new weapon system that requires earth data. These problems must be solved time and again by the inefficient application of our resources because systems that are less than fully capable for initial operations continue to be accepted. This situation is completely unacceptable considering that the solutions are really fairly simple.

The solutions to the earth data problem range from some immediate short-term steps to a longer program of change. First and foremost, education is required; the whole community involved in defense acquisition needs to increase its understanding of earth data's relationship to new weapons. We hope that this book can make a contribution to that education process. Next, the defense acquisition system needs some minor changes. These changes are primarily revisions to DOD policies and directives, but they also include standardization of the procedures by which the military departments handle earth data requirements. Finally, the users of earth data need to understand that

the technology explosion can be made to work to their advantage. New programs are underway to revolutionize earth data production and availability.

Who needs to know about and take action on the earth data problem? Many people in the Department of Defense do, especially those people who control or influence the research, development, and acquisition process. System developers, force planners, and high-level commanders in all services should also understand the nature and scope of the earth data issue. Students at the intermediate and senior service colleges—especially at those colleges committed to joint education—should study the potential for better use of earth data in the decades ahead.

2. EARTH DATA

We have coined the term "earth data" for use in this book for a specific reason. We do not want potential readers to be limited by preconceived points of view conjured up by more traditional or precise terminology. Earth data is a general term for a very complicated subject. This chapter provides the detailed information needed to understand it.

Before we can define earth data in detail we should introduce the Defense Mapping Agency (DMA). Our definition of earth data comes from specific earth data products, and DMA provides those products. In order to illustrate the breadth of the earth data problem, we have created another scenario. This one involves weapon system trainers and is only semi-fictional. We conclude by providing more detail about the scope of the earth data problem and the actions required to correct it.

Defense Mapping Agency

Who is responsible for earth data? The organization within the Department of Defense charged with responsibility for creating earth data is the Defense Mapping Agency. DMA was formed in 1972 from

Army, Navy, and Air Force mapping and charting assets. The agency now has over 9,000 people engaged in the production and distribution of its products.

The point we are stressing here is that the Defense Mapping Agency is responsible for earth data for *all* of the military services. The requirements for DMA's products are generated by the unified and specified commands and the military departments. Even though DMA is controlled by the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence, the Director of DMA is responsible to the Chairman of the Joint Chiefs of Staff for operational matters.

This book is neither specifically for nor about the Defense Mapping Agency. However, we must formally introduce DMA because of its central responsibility. We will point out DMA's involvement in the earth data problem, contending that the problems with earth data have arisen primarily in areas outside the control of DMA. We will use DMA terminology to explain earth data, and we will highlight DMA's efforts to modernize its production facilities to meet future challenges.

Other organizations, both governmental and commercial, can and do produce earth data products. Within the US government, the division of responsibilities is fairly clearly defined between DMA and other agencies such as the US Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA). The ability of non-government, commercial contractors to produce earth data is another story. In the past, contractors had very limited capabilities because the government controlled most of the source

materials to produce earth data. Now, the trend is toward commercialization of this material and increased capabilities in the hands of commercial companies. This is not necessarily bad as long as the government manages this additional resource properly.

Earth Data Defined

Earth data is quantified and codified information about the earth and the features on its surface. The traditional DOD terminology for this is *mapping, charting, and geodetic data* (MC&G). The term MC&G data, although somewhat esoteric, gives a better feel for what is included in earth data than the term earth data itself. Maps are generally regarded as graphic representations of the land areas of the earth. Charts are special-purpose maps used for navigation. Charts used for navigating ships are representations of oceans, shores, and harbors. There are also aeronautical charts for aircraft navigation. Geodesy is the science of studying the physical parameters of the earth. The two forms of geodetic data of greatest significance to the military are the precise locations of points on the earth and gravity measurements.

Our term *earth data* means the same thing as MC&G data. As we implied earlier, we think the term MC&G carries with it too many connotations of being an area for specialists only. We hope the term earth data will interest the laymen who, along with the specialists, critically need to understand the issues.

Basically, the producers of earth data need three essential elements of information: terrain, features, and location. Terrain is the data about the surface of the

earth which can be represented by contour lines. Features, both natural and man-made, are the rivers, lakes, roads, buildings, and so on, which populate the terrain. Location, also called spatial data, includes the whole system for precisely defining any specific point on the earth.

Earth data products produced by DMA can be divided into two categories: analog products and digital products. Analog products include video maps as well as the plethora of paper maps and charts for which DMA is well known. It is interesting to note that since the formation of DMA, digital products have grown from zero to over 60 percent of DMA's production efforts without any decrease in the demand for its paper products.[1]

This book deals primarily with the problems created by the proliferating requirements for digital earth data. For the most part, there are fewer problems associated with paper earth data products. DMA has received some criticism over its inability to produce paper products in the quantities required, but it has programs underway to modernize its facilities which will improve its production capabilities across the board. We will describe DMA's modernization program in Chapter 7.

The Defense Mapping Agency produces two major digital data bases of primary earth data: *digital terrain elevation data* (DTED) and *digital feature analysis data* (DFAD). The earth's surface or terrain is defined by DTED. DTED consists of the latitude, longitude, and height above mean sea level for a series of evenly spaced points on the earth's land area. Terrain data is,

for the most part, non-perishable because changes to the terrain are rare. Also, automated techniques have been developed to produce DTED.

DFAD is a positioning and coding system for listing the features, both natural and man-made, which populate the earth's surface. This data base, which includes the size of a feature, its function, the material from which it is constructed, etc., is at the heart of our problem. It is very expensive to produce because the data must be extracted and interpreted manually, and it must be updated often because the man-made features on the earth often change rapidly.

Another type of earth data required by modern weapon systems is geophysical data. Since the gravitational field of the earth is not uniform, gravitational disparities affect the guidance and navigational systems on strategic weapons such as intercontinental ballistic missiles. DMA must, therefore, produce specifically tailored digital products representing the earth's gravitational field and other geophysical parameters for each of the strategic systems.

In addition to DTED, DFAD, and geophysical data, DMA produces at least 15 other tailored digital products for specific users and purposes. Examples of these include the *digital aeronautical flight information file* (DAFIF), *terrain contour matching data base* (TERCOM), *vertical obstruction data* (VOD), *digital bathymetric data base* (DBDB), and *world mean elevation data* (WMED).[2] Some of these products are synthesized from DTED and DFAD, but others require completely different techniques to create the data. Many new weapon systems use several earth data products; for example, the cruise missile system uses both TERCOM and VOD.

We highlight the cruise missile in Chapters 1, 3, and 4 because it is another weapon system which was developed without adequate regard for the earth data needed for it to operate.

The definition of digital data is not complete without a discussion of data resolution. Data resolution refers to the minimum size of the objects which will be represented in the data set. In general, if a data set has, for example, 10-meter resolution, then any man-made object, such as a building, which is greater than 10 meters on a side will be represented. If the buildings are spaced closer than 10 meters apart, they may not be shown individually but as a solid block of buildings.

However, the definition of resolution is not very precise and requires a long list of specifications to describe the exceptions to the rule. Some objects such as railroad snow sheds or brick walls which are very long but very narrow may be required in the data set. Also, some features such as missile emplacements may be important enough to be represented in the data set regardless of size. The Defense Mapping Agency produces DTED and DFAD to several different product specifications based on resolution. (These standard products are described in Appendix A.)

The bottom line on data resolution is cost. Human analysts must do the feature analysis for earth data, making it a very labor-intensive and expensive operation. The more detail or greater resolution required in the earth data set, the greater the labor (and cost) required to produce it.

Weapon System Trainers: An Illustration

To illustrate the origin as well as the impacts of the earth data problem, let's look at another scenario that

has occurred innumerable times in the past and continues to occur today. One of the primary uses of digital earth data is in simulation and training devices. We will suppose that the Air Force has a new aircraft in operational status and now needs a flight simulator for ground training for this aircraft. The contractor has developed a prototype flight simulator as part of the development contract. The prototype simulator has added value for the contractor because it can be shown off to selected visitors as proof of its high tech capabilities.

In this particular illustration, a high ranking general officer from the operational command visits the contractor's plant. As part of the general's tour he is put into the cockpit of the flight simulator and given a short training ride. The operational aircraft has, let's say, the new synthetic aperture radar which gives incredibly clear images of the objects on the ground over which it flies. The contractor enthusiastically points out to the general that the flight simulator can duplicate this capability. In fact, in the short trainer ride, the general "flies" over the local airport and is amazed at the detail on the radar simulation screen including all of the metal landing light towers at the end of the runway. When the general leaves the contractor's facility, he is bursting with enthusiasm about the advanced training capability that his operational squadrons are about to receive. He praises the new system everywhere he goes.

The problem lies in what the general was not told. The digital earth data used in the new simulator to duplicate the synthetic aperture radar image was different from the data used in older radar simulators. The data

used for the demonstration was a special data set that was manually produced at enormous expense over a very limited geographical area. Less than 100 square nautical miles of this type of data exists in the free world; there are nearly 40 *million* square nautical miles of land area on the earth's surface. The amount of area which must be represented by data depends on many factors such as training philosophy and deployment area. Consider also that the estimates of cost in man-hours to produce this new data run as high as 244 times that for the data used in the older radar simulators.[3]

Who is at fault here? The answer is nearly everyone and, yet, no one. It is very difficult to assign blame in this situation. Let's look at each of the parties involved, one at a time.

There is a tendency, partly justifiable, to focus on uncontrolled contractor salesmanship. The contractor may be deliberately promoting a system that he knows is not adequately supported with earth data simply to make a sale. Or, the contractor may be making a genuine and unintentional error by assuming that this type of data can and will be produced in large quantities as a standard product. In fact, the data set used by the simulator in the illustration may have been supplied to the contractor by the government. The government has produced some very small quantities of this type of data for test purposes and as prototype products.

The general's only real error is lack of information. He may personally have spent many hours in the older flight trainers where conventional radar images were simulated. Data availability is not an issue for the older trainers. There is no reason to expect the general, or any other government official not directly involved in

earth data production or support, to understand all of the technical underpinnings of modern weapon systems.

The military system developer should understand the data support requirements for his system along with other critical items, such as logistics. But, on the other hand, why should he be expected to know any more about earth data availability than the general? He may not have experienced problems in acquiring earth data in the past.

Is the Defense Mapping Agency guilty? We have already pointed out that DMA is responsible for earth data support for all of the Department of Defense. But DMA was not a participant in this scenario in any way. The data set used by the contractor may have been produced as a test set by DMA, but it could just as easily have been supplied to the contractor by a third party: the system developer, for example. DMA would not be a participant in a situation like this unless someone made a point of informing it. The problem cannot be attributed to DMA.

A number of the parties involved in this illustration have done things worthy of praise. The contractor has advanced the state of simulator technology. The general knows advanced capability when he sees it, and he knows how to use it. He is right to emphasize this to the operational squadrons.

Nonetheless, this problem could potentially have a major impact on the Department of Defense. The nonavailability of digital earth data could affect the training effectiveness for virtually all of the new US military aircraft with modern sensor systems for a long time in the

future. It is also unlikely that, because of its high cost, earth data with a higher resolution than the standard DMA products will be available from any source in any quantity in the near future.

The expenses associated with increased data resolution have created a controversy over the relationship between data resolution and training effectiveness. In other words, is it absolutely necessary for mission performance (effective training) to spend enormous sums of money on data with a higher resolution than the standard DMA products? This is a very complicated controversy exacerbated by a large number of variables, such as the type of sensor being simulated, type of mission for which the training is designed, variations in data required to simulate changes in environmental conditions such as seasons, and so on. As a concrete example, does a pilot in a flight simulator need to see every landing light tower at an airfield (as in the illustration just given) in order to have effective training? As the resolution of sensors in the actual aircraft and other weapon systems continues to improve, the debate continues.

Training philosophy adds another level of complication to this debate. Digital earth data is used in simulators to provide realistic mission rehearsal training. Mission rehearsal is part of the training philosophy of our strategic forces. Tactical forces, such as Air Force and Navy tactical air elements, are moving toward mission rehearsal for their short-notice, worldwide operations. The challenge in preparing these tactical mission rehearsals is not only in higher resolution data, but also in creating, in a matter of hours, data for an unfamiliar

geographic area. Cost aside, it is not possible to quickly produce this type of data today.

Scope of the Problem

The factors which determine the scope of the problem are the number of new systems which require earth data support and the number and variety of the new earth data products called for by these systems. Most people are surprised at the number of new weapon systems being developed which require earth data; the list includes virtually every major new system. The number and variety of new earth data products required are also surprising but in a different way. For example, when the first cruise missile became operational, it required an earth data product which had never been produced before and was unique to that system. Earth data specialists spent a great deal of time and money creating the data. Other customers, such as aircraft weapon system trainers, require the same type of data, but, unfortunately, in the past each new trainer was engineered to require this data in a unique format. Since the data for one trainer could not be used in another, the government was forced to spend even more money transforming the basic data into a unique product for each trainer, essentially resulting in many different data sets for the same geographic areas.

We presented only two scenarios to introduce our subject—one involving the conventional cruise missile, the other involving an aircraft weapon system trainer—but the earth data problem is much broader than that. It also affects many other categories of weapon systems and extends to all of the military departments, several defense agencies, and various joint activities. These systems will be described in detail in the next chapter.

First, let's briefly review the magnitude of the problem.

A variety of new command and control systems are being developed by the Army, Air Force, and Navy which will require high resolution terrain and feature data similar to that required by aircraft weapon system trainers. The Army's All Source Analysis System (ASAS), an intelligence processing system to provide target data, and the Maneuver Control System, an Army corps through battalion control system, are examples. In fact, the Army is currently developing over 70 new systems which will need new digital terrain data products.

Tactical systems present some very diverse challenges. The Marine Corps' AV–8B aircraft is the first system designed to use digital earth data in a moving map display. The moving map display is tied to the inertial navigation system so that the pilot always has his map location displayed on a screen in the cockpit. This was science fiction just a few years ago. Conventional cruise missiles require even more extensive digital earth data to avoid obstacles at very low altitudes, to navigate toward, and then to strike the target.

The technology explosion and the fact that each new system is developed independently have created a seemingly endless list of requirements for new earth data products. We can't affect the technology explosion, but we can control the system development process. Therein lie the solutions to the problems created by proliferating earth data requirements.

The Solution

We propose that some minor changes be made in the Department of Defense research, development,

and acquisition process. These recommendations are explained in detail in Chapter 6. In general terms, these changes would merely give earth data the consideration it deserves and will only affect three areas. First, some key DOD directives need minor revisions relating to earth data requirements and management. Second, some earth data experts need to be given oversight and advisory responsibilities on the Defense Acquisition Board. Third, the earth data requirements process needs to be standardized across all of the military departments to assure logical consolidation of requirements. The result of this third step would be fewer *unique* earth data products required to support all of the new weapon systems.

We do not propose the usual solution—more money. Enlarging the Defense Mapping Agency budget and personnel authorizations, while perhaps a beneficial action, is not the approach recommended here. Some of the changes recommended in Chapter 6 would result in a re-allocation of money, but the net effect upon the DOD would not be an increase in Defense spending. In fact, the net effect will be to save money through the more intelligent management of Defense resources.

Education, as well as action, is required. Everyone involved in the research, development, and acquisition of new weapon systems does not have to become an expert in earth data technology. Everyone does, however, have to understand the problems and consequences that may result from ignorance of the relationship between earth data and new weapons. Also, users of earth data, both in the acquisition and operational communities, need to understand where earth data

production and distribution is headed in the future. Chapter 7 provides a look at current plans for the future.

3. MAJOR SYSTEM CHALLENGES

Did you know that there are over 70 existing and planned weapon systems that require earth data to function effectively? This number includes joint service, Army, Navy, Marine Corps, Air Force, and Coast Guard systems. The variety of forms of earth data required to support these systems is surprisingly large. Often the earth data provided is in digital form, but some systems use hard-copy map/chart products from which information is extracted. (A listing of systems is included in Appendix B.)

Each year, the number of systems requiring earth data grows because high-technology intelligent weapon delivery systems must have, at all times, a precise knowledge of where they are with respect to the earth's surface. In addition, these emerging systems require higher resolution data than ever before. Higher resolution translates into more data at finer intervals requiring considerable time to produce. Developers of weapon systems must plan far ahead to ensure the availability of the minimum earth data required for their weapons to be fully operational over any desired

geographic area. To demonstrate the variety and importance of better digital earth data, we offer the following representative examples of major systems which require this support.

Cruise Missile System

The most notable example of a system being operational without sufficient earth data is the cruise missile system. When it was deployed, its designers identified the requirement for many millions of square nautical miles of digital data. Of course, this could not be produced overnight, and in fact it did take several years to generate all that was needed to fulfill the initial data requirement. The result was that during this period of data production the cruise missile could not be used to its full potential.

A brief description of the needs of the cruise missile system and its application of digital earth information shows the magnitude and complexity of data required by the many systems.

The cruise missile is one of the most important systems for deterrence at both the strategic and theater level. As an unmanned nuclear and conventional delivery system it is capable of accurately placing warheads anywhere in the world by flying at very low altitudes. A knowledge of the shape of the terrain and the obstructions found on it is vital for pre-flight planning and in-flight navigation corrections.

The flexibility of the system is achieved by preplanning the route the missile will take to its target. The mission planners use digital terrain elevation data (DTED) together with vertical obstruction data (VOD) to literally fly the mission without leaving their desks or

consoles.[1] The DTED consists of evenly spaced elevation points, and the VOD are geographic locations and heights of known obstructions. DTED and VOD coverage of large geographic areas is required to allow all possible target options. The mission planners use many factors to design a mission that will have the highest probability of success. Terrain roughness, frequency and known accuracy of vertical obstructions, and terrain height accuracy are all used to determine where and how high the missile should fly. Extremely accurate data makes for highly successful missions.

Once the routes are planned, the next phase is to develop the data for in-flight navigation. Throughout its flight the missile is guided by an inertial navigation system. Flight errors are reduced by periodic position and velocity updates. These updates are made by use of a terrain contour matching data base (TERCOM). A TERCOM map is a rectangular area of the earth's surface divided into a number of equal-sized squares with the mean elevation of each square recorded in digital form. Using inputs from its altimeters the missile computer measures the profile of the terrain elevation below it. This measured profile is compared to the TERCOM maps stored in the guidance computer. Corrections to the guidance system are then computed based on these differences. These corrections are made in three stages: at the time the missile first reaches land (landfall); during flight (enroute); and near the target (terminal). Figure 1 shows this process. In the case of the strategic nuclear system all this planning and in-flight data must be available before specific missions can be entered into the single integrated operations plan (SIOP).

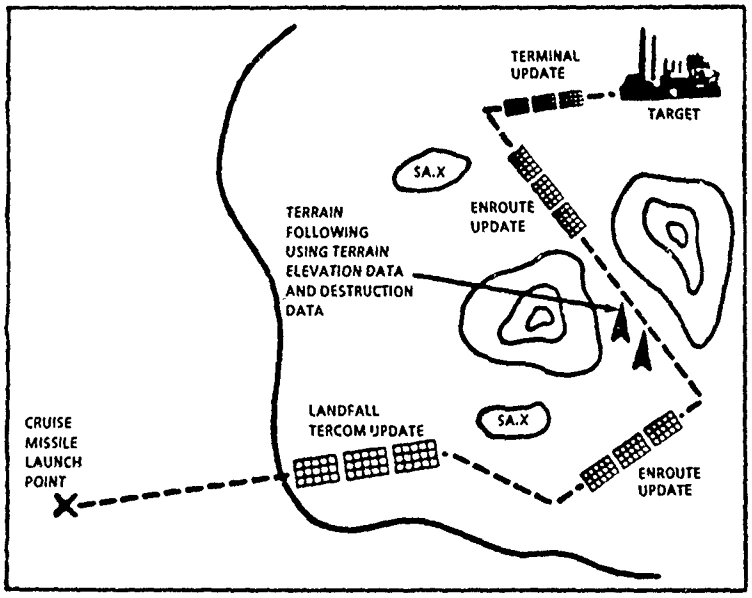


Figure 1. Typical Cruise Missile Mission

The theater conventional warhead cruise missile requires a somewhat different data set. Since it was designed for surgical strikes similar to those performed by the manned aircraft in the raid on Libya, the targeting of the conventional cruise missile is more rigorous. This missile locks onto a target by comparing a prestored digital scene of the target to the actual target. Once this match is made, the missile knows it has arrived at the proper point. Because of the need for speed and accuracy, these reference scenes are produced by the operational forces. However, in order for these scenes to be produced from reconnaissance photography, a *point positioning data base* (PPDB) must be available. A PPDB is a series of overlapping stereo

photographics that are analytically tied together. A user can select any point in the stereo model and through a series of computer driven computations obtain a ground coordinate for that point. The PPDB provides the means to correct and accurately reference the reconnaissance photography used by the missile.

The above examples suggest the quantity and types of earth data needed to make the cruise missile an effective weapon system. The best cruise missile is only as good as the digital earth data it uses. The data required for the cruise missile takes months to produce using the latest in high technology hardware and software. Thus developers must identify early in the development cycle those areas of the world where the system could potentially operate.

F–15E Weapon System Trainer

The F–15E Weapon System Trainer (WST) is an example of a developing program that will be highly dependent on earth data. The Air Force is modifying over 390 F–15C/D air-to-air fighters into dual purpose F–15E fighters.[2] This will expand their role to include close air support and deep interdiction. When modified the F–15E will become both an air-to-air and an air-to-ground system. To perform its new air-to-ground functions the F–15E must have sensors that see the ground with high resolution. These same sensors must also be employed in the WST used to train pilots.

The F–15E WST will be used for rehearsing missions in detail and for teaching aircrews to be flexible when attacking targets of opportunity. This presents a difficult problem for the trainer developer and for the earth data producers. The improved sensors on board

the aircraft make the data requirements more demanding than for other trainer/simulators.

As part of the development process of the F–15E WST, the Air Force awarded a contract to develop the data set required to operate it. This activity was well underway before the Defense Mapping Agency was consulted. The resulting data base designed by the contractor is, for reasons unknown at this time, of lower resolution than many of the standard data bases maintained by DMA. This is a recent example of a process that has repeated itself many times in the past: A major weapon system is developed or modified without early and proper pursuit of the earth data needed to make the system operate. The Air Force and DMA are now working on this problem together to provide the minimum essential data set for the F–15E WST.

B–1B Weapon System Trainer

There are other developing aircraft simulator systems that will need high and low resolution data in large quantities. The Air Force B–1B will use a synthetic aperture radar which will require its five trainers to simulate high resolution data. The WST requirements for the B–1B are still being developed but will include over 18-million square nautical miles of low resolution digital terrain and feature data plus an undetermined amount of high resolution data.

Weapon system trainers/simulators may seem like a trivial part of defense preparedness, but they are not. Current training philosophy calls for complete mission rehearsal using the actual mission terrain encountered in the strategic environment. The tactical operators are rapidly moving in the same direction. Trainers provide

the opportunity for pilots to simulate missions over hostile areas using exact representations of the terrain. The extent to which the trainers are useful for this purpose depends on the availability of the digital data. The diverse and sometimes unknown mission locations, plus the short time for preparation, further exacerbate these problems.

Battlefield Information Systems

In the mid-1970s a number of intelligence and tactical battlefield systems began to evolve. These were automated displays designed to give the commander more timely information about the enemy and also data on the terrain and environment in which he would be fighting. The Army, for example, has used specialized products known as *terrain analysis data bases.* These are a family of products that offer more fully interpreted information than the standard topographic map. A series of overlays are produced that give detailed information on vegetation, soils, slopes, surface drainage, and obstacles to transportation. These products are used by the terrain analyst and the commander in the field for battlefield planning and strategy. The developing systems are trying to satisfy these information needs in a digital form with real time interactive display systems.

Similar systems to support intelligence needs are also being developed. These intelligence systems will need large amounts of earth data (mapping and charting information in digital form) to operate. The mapping and charting data provides the backdrop on to which the intelligence information is displayed and referenced. For example, data regarding military operations carried out in a particular physical structure is useless without a precise location of the building and

its relationship to the terrain. (We will discuss more details of this emerging earth data requirement in Chapter 7.)

Trident II Sea Launched Ballistic Missile

The Navy's new Trident II submarine equipped with the D5 missile system is another example of a major system heavily dependent on earth information. The strength of the SLBM is its ability to launch from anywhere, thus effectively eliminating it as a target from hostile forces. In order to launch its missiles from the sea accurately, the Trident system must have information about the geopotential or energy needed to lift the missile at the launch site. This means that worldwide gravity data must be available for use by Trident II.

Mobile Missile Systems

The evolving concept of the mobile Intercontinental Ballistic Missile (ICBM) has serious earth data implications. The data to support a US deployment and the data to help detect a Soviet deployment are potentially enormous. In the case of a US deployment, large quantities of precise launch location data will be required. In particular, the exact earth position and the launch region gravity parameters must be known for all potential launch sites. The fact that the system is mobile and can be fired from any place greatly expands the potential data requirement.

Detection of possible launch positions of Soviet mobile missiles represents the other side of the problem. The terrain of the Soviet Union must be thoroughly analyzed to determine likely launch areas. This involves large quantities of earth data in digital form.

Probable areas can be extracted by assuming certain slopes, vegetation, and other conditions. Once the likely areas are determined, a detailed study of these areas can be made to provide the most likely positions of the mobile launchers. Mobile missile detection represents some very challenging problems. The key to success is our knowledge of the terrain and the features on the terrain. The quantity and quality of the data will ultimately determine our ability to build a deterrence against this threat.

The Impact

The evolving earth data requirements—and, in particular, the high resolution data we have discussed— have the potential to become a very serious problem for the Defense Department. Newer weapons are being built with more and more accuracy as the transition from intelligent systems to brilliant systems is made. These new systems demand more earth data and greater accuracy to achieve their objective. What effect will the lack of earth data have on these new trainers? What is the impact of aircrews not being able to rehearse a SIOP mission? What is the impact of limiting the patrol area of the Trident II? Will we be able to locate hostile mobile missile sites? What overall effect do these factors have on our deterrence posture? The summary answer to these questions is that our defense posture is degraded, so we are forced to waste our resources to correct the problem.

We believe that the defense acquisition system ultimately has a greater effect upon the earth data problem than some of the more obvious factors such as the budget of the Defense Mapping Agency. In the next

chapter, we will examine the defense acquisition system and its relationship to earth data for new weapons. The system has run amuck where earth data is concerned, allowing the earth data users to present the data producers with untimely and needlessly burdensome requirements.

4. THE DEFENSE ACQUISITION SYSTEM

Consideration of earth data has historically been peripheral and not integral to the defense acquisition system. This is no longer sufficient to support the research, development, and acquisition of modern weapon systems. Some defense officials have recently recognized the problem and made efforts to improve the situation. This chapter reviews the overall defense acquisition system as it relates to earth data, and it reports on the recent efforts to raise the visibility of earth data issues. The chapter concludes with a brief acquisition history of an actual major system, the cruise missile, to show how the acquisition system itself can be at fault.

The defense acquisition system is continually in a state of refinement and modification. This chapter will identify and categorize major changes in the process and the various motivations for these changes. These changes include reducing the acquisition time, increasing competition between contractors, and improving the overall efficiency of the acquisition process. But the two primary motivations were and remain to save

money and to procure a better product or weapon system for the fighting forces. All of the reasons for introducing changes are based on good intentions.

Major revisions in the defense acquisition system generally coincide with changes in Defense Department personnel. This is consistent with the nature of the US government. Each administration or senior leadership group in the Department of Defense seeks to put its own stamp on the department, and the acquisition process tends to be a primary target. Seldom does a major change result from an independent study highlighting a problem in the middle of the tenure of an administration. Regardless of the timing, however, we hope that this study will bring about a change in the acquisition process specifically as it relates to earth data considerations for new weapons.

Knowledge of the defense acquisition system as a whole is necessary in order to understand why and how earth data considerations must be integrated into the system. An evolutionary process produced the current system. Many people were familiar with the old system as it existed up to 1985. Some are familiar with recent changes. In order to put everyone on the same knowledge level, we will begin with the system's evolution.

The period of evolution of the defense acquisition system important to us runs from 1969 to the present. This can be roughly divided into three time periods. First, we discuss the relatively static system that existed from 1969 to 1985. Then we review some major changes that were made in the period 1985 to 1987. Finally, we examine the system as it exists today. Some of

the initiatives which were taken from 1985 to 1987 related directly to the consideration of earth data for new weapons. While these efforts were necessary and helpful, they do not fulfill the long-term needs of the Defense Department. We will begin with the heart of the defense acquisition system.

Both the background of and the solutions to the earth data problem lie in the structure of the defense acquisition system. The system as it existed in the past allowed earth data to be overlooked in the research, development, and acquisition process. The system as it exists today allows that same mistake to be repeated.

The Governing Structure

The defense acquisition system for major weapon systems is controlled by a governing body at the Department of Defense level. From 1969 to 1985, the Defense System Acquisition Review Council (DSARC) was the primary body controlling the acquisition system.[1] The DSARC was replaced by the Joint Requirements and Management Board (JRMB) in June 1986.[2] The JRMB was a short-lived body, replaced by the Defense Acquisition Board (DAB) in early 1987.[3]

Deputy Secretary of Defense David Packard created the DSARC in 1969. The council, composed of senior defense officials, was designed to provide top-level advice to the Secretary of Defense on major acquisitions. It was intended to retain central authority over the acquisition process while decentralizing day-to-day management. The structure and function of the system involved review of the major programs at three *milestone* reviews.

It is extremely important to understand the milestone process because, although the governing body

has changed, the milestone system has remained. We will begin by describing the DSARC system. Then as we look at the new system, the DAB, we will highlight the modifications to the milestone process because these modifications created the system in place today.

Under the DSARC system, major programs were created before the milestone process took effect. The Secretary of Defense authorized the start of a new program in response to a perceived threat. With this authorization, the appropriate service initiated a program office to explore the alternative concepts to counter the threat. A program manager directed this effort called the Concept Development Phase.

Milestone I, the first review of the program, came at the end of the Concept Development Phase. Under the DSARC system, Milestone I was a formal review chaired by the Under Secretary of Defense for Research and Engineering (USDRE). The Secretary of Defense then made his decision on how to proceed based on the DSARC Milestone I review. A decision to proceed moved the program into the Demonstration and Validation Phase.

The Concept Development Phase which culminates in Milestone I is extremely important to the earth data problem. During this phase, system developers and contractors start to consider engineering approaches to hardware development. The system developers can take one of two possible alternatives at this point if earth data is required for the new system. First, they can engineer their system to use earth data which already exists as a standard Defense Mapping Agency (DMA) product. This is almost always the most cost effective and desirable approach. Second, the system developers can engineer their hardware to use a totally

new earth data product. If this second approach is absolutely necessary, the earth data producer, DMA, needs as much development time as the weapon developer to design the new earth data product and engineer a new production capability. The importance of the Concept Development Phase will be reiterated in Chapter 6 when our recommendations are presented.

During the Demonstration and Validation Phase the alternative concepts proposed earlier and approved at Milestone I were tested. The key feature of this phase was prototyping. The program manager used the test data from the prototype hardware to prepare for Milestone II.

Milestone II was really the most significant step in the system acquisition process. As in Milestone I, the DSARC was required to meet, review the program, and make a recommendation to the Secretary of Defense. Milestone II is significant; a decision to proceed at this stage constituted a financial commitment on the part of the government to authorize Full Scale Development. Considerable resources became committed to a single approach to counter the perceived threat. Full Scale Development took the program up to a point just short of mass production.

It took a Milestone III review to authorize production and deployment. Under the DSARC system, the service secretary made the Milestone III decision, but this was somewhat of a formality unless conditions had changed significantly since the previous decisions had been made.

On 3 June 1986, Deputy Secr. of Defense William H. Taft IV replaced the Defense System Acquisition Review Council (DSARC) with "a restructured"

Joint Requirements and Management Board (JRMB). A Presidential Blue Ribbon Commission on Defense Management, known as the Packard Commission, had recommended establishment of a JRMB along with several other changes in April 1986. Deputy Secretary Taft referred to the new JRMB as "restructured" because a board called the Joint Requirements and Management Board already existed under the management of the Joint Chiefs of Staff (JCS). Mr. Taft directed that the previously existing board be renamed and continue to carry out its responsibilities as directed by the JCS. These actions were temporarily accomplished by memorandum until formal DOD directives could be published.

Deputy Secretary Taft's memorandum also directed the following:

> • The Under Secretary of Defense for Research and Engineering [USDRE] will chair *all* milestone reviews until the establishment of an Under Secretary of Defense for Acquisition.
> • The Chairman of the Joint Chiefs of Staff (JCS) will designate a representative to serve as vice chairman of the JRMB until the establishment of a vice chairman of the JCS.
> • The members of the old DSARC will serve on the new JRMB.
> • The Deputy Secretary of Defense [Mr. Taft] will continue to serve as the Defense Acquisition Executive.
> • The [USDRE] will revise DOD Directive 5000.1, "Major System Acquisitions," and DOD Instruction 5000.2, "Major System Acquisition Procedures," to reflect these changes.[4]

Other Taft changes, including some of those recommended by the Packard Commission, were alluded to in the memorandum, but were so significant that

they required an act of Congress in order to be accomplished. Congress passed the necessary legislation in the form of the Department of Defense Reorganization Act of 1986. Known popularly as the Goldwater-Nichols Act, it was signed into law, becoming Public Law 99-433, on 1 October 1986. The Goldwater-Nichols Act was the first major legislation affecting DOD organization since 1958. It prescribed some significant changes across the entire Department of Defense, changes that, in fact, went beyond the recommendations of the Packard Commission. The changes of particular interest here were the establishment of two new positions, the Under Secretary of Defense for Acquisition and the Vice Chairman of the Joint Chiefs of Staff.

The changes proposed by the Packard Commission and mandated by the Goldwater-Nichols Act started to come to fruition with the appointment of Mr. Richard Godwin as the Under Secretary of Defense for Acquisition. Mr. Godwin eliminated the projected Joint Requirements and Management Board before it was ever formally established. He replaced it with the Defense Acquisition Board. The DAB was formally initiated by DOD Directive 5000.49, Defense Acquisition Board, 1 September 1987.

More than just the name changed with the establishment of the Defense Acquisition Board. The key changes dictated by DOD Directive 5000.49 affected the membership of the DAB as well as its responsibilities and functions:

- The Under Secretary of Defense for Acquisition will chair the DAB. [The DSARC had been chaired by the USDRE. The Packard Commission had recommended a single, more powerful acquisition executive.]

- The vice chairman of the JCS will serve as vice chairman of the DAB. [The chairman of the JCS was a member of the DSARC, but the DSARC had no vice chairman. The addition of a vice chairman of the JCS in a leadership role in the DAB gave the operational forces a direct input into the acquisition process.]
- Service Acquisition Executives [SAEs] for the Army, Navy, and Air Force [designated by the military departments] will serve on the DAB. [The service secretaries had been members of the DSARC, but the role of the military departments was clarified and strengthened by the establishment of SAEs.]
- Total membership of the DAB will be reduced to include the following:
  + Assistant Secretary of Defense (Comptroller)
  + Assistant Secretary of Defense (Production & Logistics)
  + Assistant Secretary of Defense (Program Operations)
  + Director of Defense Research and Engineering
  + Director of Program Analysis and Evaluation
  + Chairs of the Acquisition Committees, as appropriate.
- The Under Secretary of Defense for Acquisition will become the Defense Acquisition Executive [DAE].
- Recommendations of the DAB forwarded to the Secretary of Defense will include any dissenting opinions of the DAB members on substantial issues.[5]

The overhaul of the defense acquisition system included many more changes which affected not only the basic structure, but also earth data factors. Key among these changes was the overhaul of the milestone system. While the new defense acquisition system does not solve earth data problems, it does offer a structure which can be made to accommodate earth data considerations.

Regulatory Guidelines

Two Department of Defense regulations were significant in the overhaul of the basic structure of the defense acquisition system. The Under Secretary of Defense for Acquisition published a new DOD Directive (DODD) 5000.1 and a new DOD Instruction (DODI) 5000.2 on 1 September 1987. Even the names of these defense regulations were changed. The new DODD 5000.1 is entitled "Major and Non-Major Defense Acquisition Programs," vice the old "Major System Acquisitions"; the new DODI 5000.2 is "Defense Acquisition Program Procedures," vice the old "Major System Acquisition Procedures."[6] References made here to the "new" system will mean the provisions established by the 1 September 1987 regulations.

These new DOD regulations made a number of major and minor modifications to the defense acquisition system. The three major changes were the addition of three new milestones in the decision process, the introduction of a streamlined organization with a shorter chain of command, and the introduction of acquisition committees. We will concentrate on these not only because they were the new elements of the system, but also because they established a structure which will facilitate proper consideration of earth data issues.

Major new systems must now undergo six milestone reviews by the DAB. The first, Milestone 0—Program Initiation/Mission Need Decision, is new. This is virtually unchanged from the DSARC system, but now it is given milestone status. The DAB does not meet to

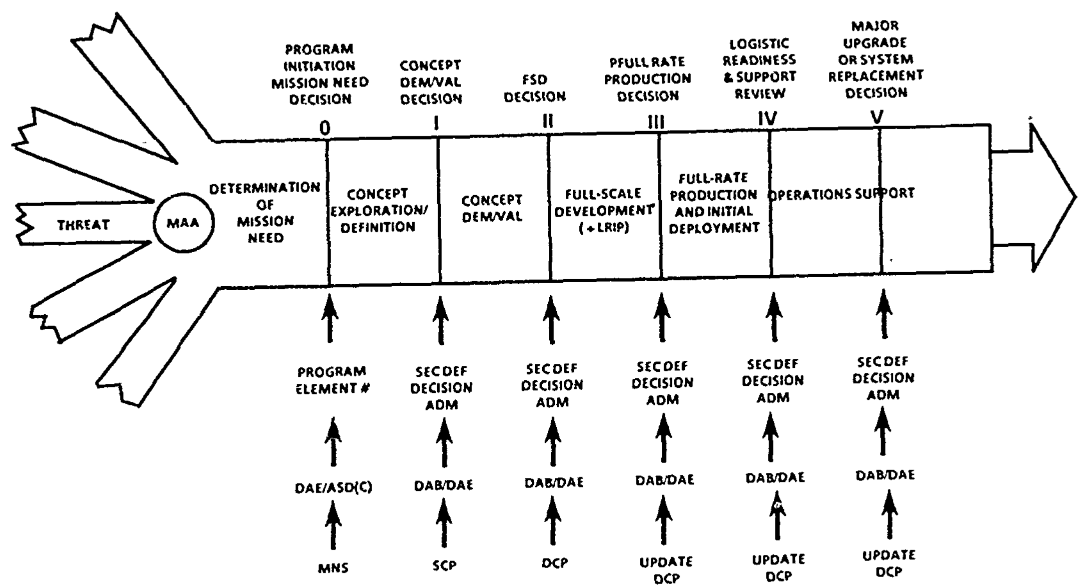
approve this milestone, the Defense Acquisition Executive can authorize a major new system start. Milestones I, II, and III remain very much the same as they were in the DSARC system. For clarity, they are

- Milestone I—Concept Demonstration/Validation ("Concept Development" under DSARC) Decision,
- Milestone II—Full Scale Development Decision, and
- Milestone III—Full Rate Production Decision.

Milestones IV and V are new. Milestone IV—Logistics Readiness and Support Review—will identify actions and resources needed for operational readiness and support for the first several years of deployment. Milestone V—Major Upgrade or System Replacement Decision—normally will occur five to ten years after deployment to consider the alternatives for the future life of the system. Figure 2 shows a diagram of the milestone system as it exists today.

A streamlined chain of command is one of the key features of the new system. There will be only two people between the Under Secretary of Defense for Acquisition functioning as the Defense Acquisition Executive (DAE) and the Program Manager. They will be the Service Acquisition Executive (SAE) reporting to the DAE and the Program Executive Officer (PEO) functioning under the SAE. The SAEs are senior civilians designated by each of the military departments. The PEOs will normally be general officers responsible for large research and development organizations. The role of the Program Manager, working under the PEO, is fairly straightforward. A Program Manager is the one person responsible for the development activities associated with each major system.

FIGURE 2
MAJOR DEFENSE SYSTEMS ACQUISITION PROGRAMS



Another new feature of the system is the introduction of acquisition committees. The Defense Acquisition Board is supported by ten acquisition committees. Each committee has its own area of oversight such as nuclear weapons, conventional systems, science and technology, and so on. These committees meet prior to a DAB meeting and are charged with reaching consensus on the issues to be presented at the coming meeting, the place where the real substantive discussions are held. That is why the DAB acquisition committees are so important to the topic of this book. These acquisition committee meetings offer a forum to ensure that earth data considerations can be addressed at the right time in the acquisition process.

DODD 5000.1 and DODI 5000.2 had not mentioned earth data, explicitly or implicitly, before their 1 September 1987 revisions. The director of the Defense Mapping Agency (DMA) at that time, Major General Robert Rosenberg, led a concerted effort to have appropriate wording inserted into the revisions. These efforts met with only partial success. Neither regulation incorporated DMA's proposals verbatim. For DODD 5000.1, DMA proposed that the words "operational support data" be added as a necessary consideration along with such items as logistics and manpower; the change was not made.

The proposals and the changes to DODI 5000.2 were more complicated. The new DODI 5000.2 does include specific references to earth data, but they differ from those proposed by DMA.[7] First, DMA desired that the reference list include DODD 5105.40, Defense Mapping Agency (DMA), 23 April 1986. This was accomplished. Second, DMA wanted to make earth data

a mandatory consideration at each milestone review. The previous DODI 5000.2, dated 19 November 1985, had an Enclosure 2 entitled "Acquisition Management and System Design Principles," which functioned as a checklist for Program Managers. (*See Appendix* C.) DMA proposed to add a reference to earth data to this enclosure. When the new DODI 5000.2 was published, the checklist had been deleted, because the Under Secretary of Defense for Acquisition had ordered that the regulation be reduced in size. In the 1 September 1987 revision of DODI 5000.2, the Mission Need Statement Format (Enclosure 3) and the System Concept Paper and Decision Coordinating Paper Formats (Enclosure 4) include specific words on "mapping, charting, and geodesy" considerations.

Are these changes sufficient to make a difference? Well, they are certainly steps in the right direction, but it is our contention that they are not adequate. Words buried in text are not as good as a separate line on a checklist. Furthermore, the people who run the defense acquisition system must be made personally aware of the necessity for proper consideration of earth data issues. The manner in which this can be done will be covered in later chapters.

PDM–85 is a Program Decision Memorandum which was issued by the Department of Defense in 1985. It directed a major change in the way that system developers plan and program for earth data to support new weapon systems. This PDM was the major change in DOD policy in the 1985 to 1987 period dealing directly with earth data. It placed the burden of funding for new earth data products on the users of that data.[8] It had shock value and raised the awareness of earth

data throughout the development community. It also engendered a whole host of counterproductive reactions. However, it did not change the basic structure of the defense acquisition system. (For this reason, and the fact that this document is central to the topic of this book, PDM–85 is discussed by itself in Chapter 5.)

Cruise Missile Development: An Illustration

Now that we have described the defense acquisition system, let's see how it has guided the procurement of an actual system, the cruise missile. This illustration is similar to the scenarios presented in Chapters 1 and 2 in that it is intended as an example of the points being made, but this illustration is different in that it is totally factual. We chose the cruise missile because it was one of the first of the modern weapon systems which required earth data in order to function. The development of the cruise missile was regarded by many as a model of success, but how well did the defense acquisition system accommodate the requirement for new earth data products?

The development of the modern cruise missile is as much a story of failure as of success. The success story has been told many times; it is the application of new technology to an old military problem. The story of failure has received considerably less publicity. It is the story of the failure of almost everyone involved to understand the necessary elements of support for this new technology. Earth data is the critical element of support for cruise missiles, yet it was virtually ignored by the system developers and the defense acquisition staff in the Pentagon. It is easy to see how, in the past,

these mistakes were made. The developers were dealing with an entirely new technology. However, it is our contention that today system developers continue to make these same mistakes because the defense acquisition system allows them to.

Both the Air Force and the Navy have long wanted an accurate stand-off weapon. The Navy actually pursued a "flying bomb" project during World War I with no success.[9] It was the Germans who made the first real progress toward a true stand-off weapon with their V–1 program during World War II.[10] By 1956, the US Air Force issued an Operational Requirement for an air-to-surface missile for the B–52 long range bomber. The missile that was developed and deployed was the Hound Dog, but it was not particularly accurate.[11]

During the 1960s and early 1970s, advancements were made in inertial guidance systems and digital computer technology which made the modern cruise missile able to fly from point A to point B very accurately. But advancements in digital computer technology really made the cruise missile possible. The new digital technology allowed the missile to store data about the terrain over which it would fly. Not only could the computer on the missile store map data, but it could also analyze the data, determine the missile's location, and correct the flight path as required. In essence, the missile computer had replaced both the paper map and the human navigator. Before we discuss the use of earth data in missile guidance, however, let's look at the organizational developments and decisions which paralleled the technical developments.

Three types of cruise missiles were considered for development: an Air Launched Cruise Missile

(ALCM), a Sea Launched Cruise Missile (SLCM), and a Ground Launched Cruise Missile (GLCM). Throughout the early 1970s, the Navy pursued a variety of programs including both underwater launched cruise missiles and surface launched systems. The Air Force was similarly studying air launched missile systems. The development of the ground launched cruise missile didn't come until the late 1970s, but when it did, responsibility for it too was given to the Air Force.

In 1973 both the Air Force and the Navy initiated the programs from which the modern cruise missiles came. While there was a considerable amount of diverse investigation during this time, the thinking of the Air Force and the Navy converged to a surprising degree. By 1977 both were ready for Milestone II by the Defense Systems Acquisition Review Council (DSARC II).

This particular DSARC II was extremely important both for what it did and what it did not do. It authorized both the SLCM and the ALCM to begin full-scale development. It also directed the Navy and the Air Force to form a Joint Cruise Missile Program Office (JCMPO) to manage these efforts.[12] What it did not do was recognize that some action was necessary to ensure that the essential earth data would be developed and produced to support the cruise missiles. Essentially, these wonderful weapons would be flying blind. Should we have expected the defense acquisition managers to recognize this as a deficiency? The defense acquisition directives were no help, and there was no history to tell them that they were making a mistake.

The cruise missile was the first weapon ever developed which carried and used digital earth data on

board the weapon itself. Therefore, one could say that these defense officials were confronted with an entirely new situation and could not be expected to recognize this need. On the other hand, the earth data was essential to the function of the cruise missile. We can say that someone should have recognized this unique support requirement as a potential problem, but no one with the right background or talents was apparently in the right place at the right time to make this assessment.

We described the earth data required to support the cruise missile in Chapter 2. The cruise missile requires as an absolute minimum Digital Terrain Elevation Data (DTED) and Terrain Contour Matching (TERCOM) maps.[13] While DTED was a standard product of the Defense Mapping Agency, TERCOM was a brand new product developed by the agency for the cruise missile. The Defense Mapping Agency requires a considerable amount of time, just as the weapon system developer does, to design and engineer a production capability for a new product.

Because DSARC II approved full scale development of the cruise missile without consideration for the necessary earth data, all parties involved muddled along doing their best to plan for support of the system. The JCMPO and DMA were in communication from the time the joint program office was formed. Since DMA had developed TERCOM for cruise missile test purposes, it had also acquired some limited expertise in data production. The problem was one of magnitude as we shall see.

By the time the production contract for the Air Launched Cruise Missile (ALCM) was awarded in 1980, DMA was behind the power curve. DMA had

hand-built a few TERCOM matrices at considerable expense in manpower, but they had not designed and built a mass production capability for TERCOM. The production contract called for Boeing to produce 3418 ALCMs.[14] The initial request for data from the Strategic Air Command was relatively small, but, as the total requirements began to be known, they began to look overwhelming. Because each missile required several TERCOM matrices, DMA was faced with a requirement for thousands of data sets.

Not everyone agrees that the lack of earth data support for the cruise missile created a crisis. In fact, a report written by the Rand Corporation cites the interagency coordination during the development of the cruise missile as a model for other system developers.[15] In some respects, this is true. Coordination did take place between the Program Office, DMA, operational commands, and contractors. The people involved worked very hard to solve the problems that confronted them—but these people were all at the working level. Our point here is that the Pentagon decision makers placed these people at a terrible disadvantage. The milestone decision which authorized money for the production of the cruise missile *did not* authorize the concurrent expenditure of money for the production of the necessary earth data. The working level people were behind before they had even begun.

Turning to the record of cruise missile support requirements and their impact, the ALCM reached initial operational capability (IOC) in 1982. The SLCM was close behind, reaching IOC in 1984 for both submarines and surface ships. By the time this IOC period arrived,

the operational commands were demanding 8000 TERCOM matrices.[16] Also, a large number of these matrices were from areas where DTED did not yet exist so this represented a double burden. The double burden involves first producing the DTED and then producing the TERCOM. It took DMA five years of "crash" effort to fulfill these requirements. In the meantime, the Department of Defense could employ this new multi-billion dollar system only in very limited geographical areas of the world.

The problem of earth data support is not unique to the cruise missile development. Many new systems are being developed which will require earth data support. When the cruise missile was built, the earth data support issue was new, and the lack of consideration for earth data was understandable. The problem is that the lessons from the cruise missile/earth data mismatch have not been learned. Major new systems which require earth data continue to be developed without considering where this data will come from. The large number of systems in development which require earth data will magnify this problem to crisis proportions.

The reason that people keep repeating the same mistake is that defense guidance is inadequate in the area of earth data support for new weapons. This chapter presented the defense acquisition system as it exists today and the kind of errors in earth data support that result from it. The recommendations for changes in the defense acquisition system explained in Chapter 6 are intended to prevent these errors from recurring. Before we proceed to the recommendations, however, we need to discuss another document of defense guidance which requires change, PDM–85.

5. PROGRAM DECISION MEMORANDUM-85

A document commonly called PDM-85 is the most important single enactment by the Department of Defense affecting earth data users since the formation of the Defense Mapping Agency in 1972. We will describe what PDM-85 is, why it was absolutely necessary, and why it failed in the long term. We will also outline in detail the steps that need to be taken to make the acquisition process work as it should with respect to earth data.

PDM-85 is a Program Decision Memorandum for the military departments and the Defense agencies signed by Deputy Secretary of Defense William H. Taft IV on 22 August 1985. Four versions were issued: one each for the military departments and one for Defense agencies.[1] We are specifically interested in the three for the military departments although only a small portion of PDM-85 deals with earth data. And while most of the memorandum is classified, the earth data provisions for the military departments are unclassified. Consequently, all discussion of PDM-85 in this book is at the unclassified level.

The provision of PDM–85 affecting earth data states that *beginning in FY 1988, each military department must fund within its own resources the cost of unique earth data products*.[2] This is a fundamental change. Prior to PDM–85, the Defense Mapping Agency was responsible for funding the development and the production of all earth data products.

PDM–85 thus institutes a partial industrial funding situation where the system developer will have to provide the funds to DMA for unique earth data products. For example, if a Program Office develops a new missile that requires an entirely new earth data product to support its guidance system, then the Program Office must provide funds for the new earth data product along with its other development costs. On the other hand, if a Program Office develops a new missile that uses only standard Defense Mapping Agency products to support its guidance system, then DMA is responsible for the cost. (*See Appendix D.*)

The brief paragraph in PDM–85 goes even further; it directs the actions of the military departments with respect to earth data support. PDM–85 charges the military departments to review ongoing programs to identify the need for any unique earth data products and to program the necessary funds as new systems enter full-scale development. This timing is important, as we saw when looking at the illustration on cruise missile development in Chapter 4. DMA requires as much lead time as possible to develop the production capability for a new product.

On 6 June 1986, Deputy Secretary of Defense Taft added some real meat to PDM–85 by issuing an implementation plan for its earth data provisions.[3] One of

the key contributions of the implementation plan is the establishment of a threshold level for applicability of the PDM. The implementation plan states that PDM–85 only applies if the unique earth data costs more than $1 million or 30 man-years to produce in any given fiscal year. The implementation plan also specifies the timing and responsibilities for the various aspects of earth data planning for a new weapon system. It clearly indicates that initial contact between the system developer and DMA must occur immediately after program initiation—Milestone 0 under the new Defense Acquisition Board system. (*See Appendix E.*)

Why was it needed?

The various factions within the DOD which supported PDM–85 had their own motivations for doing so. Two primary motivations can be identified. First, there was a general recognition by many that inadequate attention to earth data was causing some major problems as new weapon systems approached completion. This is the primary issue we are dealing with, and we will assess whether PDM–85, in fact, contributed to solving it. Second, PDM–85 was intended to eliminate one of the hidden costs to new weapon systems. However, this has yet to be accomplished since, as we will show, PDM–85 has failed to function as intended.

By 1985, the continuing problem, addressed in Chapter 1, of system developers building systems without consideration for the essential support data (earth information) made some directive such as PDM–85 absolutely necessary to shake up the defense acquisition community. As Chapters 2 and 3 show, the problem was a daunting one by 1985.

The future of the problem appeared even more frightening. It seemed that virtually every new system used for targeting, navigation, intelligence, or training needed earth data. The explosion in technology made it possible to develop a plethora of systems with each one requiring its own unique earth data product. With no controls in place, that was exactly the direction in which systems developers seemed to be headed. The problem with this was that each unique data base requires a great deal of time and expense to compile.

Why did it fail?

In spite of its good intentions, PDM–85 was doomed to fail in the long run. Granted, it did succeed in getting the attention of many of the right people, and that was good. But in the end, it proved to be an unsupportable document.

The primary reason for the failure of PDM–85 was that its provision of partially reimbursable funding was perceived as unfair to the community of earth data users. The military services are always somewhat unhappy with the portion of DMA production devoted to their product requirements. This is because the JCS priority system for the allocation of DMA resources favors some missions over others, such as strategic over tactical. The reimbursable funding instituted by PDM–85 exacerbates this resentment. To date, none of the military departments has wanted to establish the precedent and be the first to transfer funds to DMA for earth data. They would rather limit their operations than pay for a product they consider to be DMA's financial responsibility.

The Navy's decision on gravimetric data for Trident II submarines illustrates the point clearly. The

earth data paragraph in PMD–85 for the Department of the Navy contained an extra sentence. This sentence directed the Navy to review the need for gravimetric data for Trident II and program funds in FY 1988 to continue DMA support. Initially, the Navy promised to do this. Based on that promise, DMA programmed significant computer and personnel resources for the effort. Then the Navy changed its mind and told DMA that it would need no additional gravimetric data until 1991. What this did to the Navy's operational capabilities is unknown, but it is clear that they could not expand their patrol areas during this three year hiatus. This decision also created confusion and caused considerable reprogramming of resources for DMA. We can speculate that by placing Trident II funding in the out years of their annual budget request, the Navy was hoping that by 1991 either PDM–85 would be gone or there would be some other alternative.

PDM–85 and its implementation plan generated considerable controversy over interpretation of their provisions. Specifically, what earth data products are or would be covered by PDM–85? Who has to pay and who doesn't? PDM–85 uses the words "unique mapping, charting, and geodesy (MC&G) products." What is meant by unique? The implementation plan further confuses the issue by using the phrase "new, unique MC&G products" and also by referring to "system unique products." The result was confusion and controversy. No system developer wanted to be the first to establish the precedent of paying for earth data products. All involved interpreted the wording to their own advantage.

The PDM–85 issue is further clouded by the fact that there is no clear process to adjudicate problems of interpretation and to render decisions. The implementation plan identifies the DOD MC&G Requirements and Programs Review Group as the forum to which the various parties can provide recommendations, but this group reports to the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence [ASD(C^3I)]. The implementation plan also states that the ASD(C^3I) will advise the Secretary of Defense on issues such as cross-service implications and appropriate funding levels. Obviously, problems of resolving issues of interpretation of wording and funding for earth data support should not be bumped all the way up to the Secretary of Defense. But no one in the Department of Defense is clearly given the authority to render judgement on the issues, including the MC&G Requirements and Programs Review Group. Even if there were such an authority, how would it require the services to program funding? We have seen that given the choice to procure another ship versus gravity data, the Navy chose the ship. This is not a problem of a particular service; if similar circumstances were faced by the Army or the Air Force, that service would probably make the same choice.

Another objection to PDM–85 is the possibility that even if it worked as written, it would actually inhibit technological innovation. Some system developers were so adamant about not funding Defense Mapping Agency costs for earth data that they started to look at alternative sources of earth data products, such as commercial contractors, to support their systems. Other developers even considered downgrading

the capability of their new systems. Data procured from commercial sources is generally not as accurate as or compatible with DMA data. Taken to the extreme, this search for alternatives to DMA data could be a problem. We do not want to sacrifice operational capability over the issue of whose program element will provide funds for earth data support. DMA wants to work with system developers to explore the use of standard earth data products as the primary approach to support new weapons.

In the final analysis, the earth data section of PDM–85 was based on good intentions, and it achieved a high level of awareness in the system development community about the issue of earth data support. But, PDM–85 is clearly not a workable directive in the long run. Chapter 6 contains recommendations for an alternative approach to funding for earth data.

6. RECOMMENDATIONS

The remainder of this book deals with the future. This chapter contains recommended changes to the defense acquisition system which are needed to ensure adequate consideration of earth data in the research, development and acquisition process. These recommendations are directed at the Department of Defense and the military departments.

In Chapter 7, we describe future production of earth data and the implications of standardization. Because the Defense Mapping Agency is the Department of Defense agency for earth data production, Chapter 7 focuses on DMA and its program of production modernization. Efforts now underway at DMA are important to the whole defense acquisition community. The last chapter, Chapter 8, is our assessment of the future. In it we predict success for earth data support to future weapon systems.

The problems of earth data support for weapon systems are fundamental, but the solutions are relatively simple. The changes in the defense acquisition

system recommended here are indeed easy to implement. Furthermore, these changes are essential because the process of considering and handling earth data support for new weapons must be "institutionalized." By this we mean that the changes must carry the force of regulations and become established procedures. We must establish procedures and documentation requirements which will remain in place after the personalities in power change.

Update DODI 5000.2 with a Checklist

The regulation which controls the defense acquisition system is the key to ensuring adequate earth data considerations. Department of Defense Instruction (DODI) 5000.2, Defense Acquisition Program Procedures, 1 September 1987, is that regulation.[1] Although the current version of DODI 5000.2 was published fairly recently, it needs one minor addition.

DOD Instruction 5000.2 needs a specific checklist. This should be a simple, one-page attachment to the instruction listing areas of mandatory consideration in the defense acquisition process. The types of items which should be included on the checklist are maintainability, interoperability, training, environmental impact, and, of course, earth data support.

Real consideration of the items on the checklist must be mandatory in order for the checklist to have value. The instruction must require the preparers of the Mission Need Statements (MNS), System Concept Papers (SCP), and Decision Coordinating Papers (DCP) *to document* their consideration of each item at

each milestone review. Some items such as maintainability will apply to all weapon systems. Other items such as earth data support will only apply to some specific systems. The documents presented for milestone review must show which items apply and what the status is of each applicable item. We also propose to give the Defense Acquisition Board, which controls the milestone reviews, a little help in the form of an advisory earth data expert. That is the subject of the next section, but, first, we need to explore the checklist idea in more detail.

The previous regulation was inadequate for several reasons. As discussed in Chapter 4, DODI 5000.2, 19 November 1985, had a checklist attached as Enclosure 2, "Acquisition Management and System Design Principles." (*See Appendix C.*) The instruction, however, merely specified that these principles "shall be considered in planning major system acquisitions."[2] The greatest inadequacy of this checklist was that earth data support was not included.

The current regulation, 1 September 1987, has its own inadequacies. In an effort to decrease the number of pages in the new instruction, the checklist was dropped completely. In place of the checklist, text was added to the enclosures on Mission Need Statement, System Concept Paper, and Decision Coordinating Paper formats. Fortunately, specific mention of earth data support was added to each enclosure. But there are two problems with this approach: first, text is less explicit than a checklist; second, the items in the text are meant to be representative, not inclusive. The enclosures direct that items "such as maintainability," must be described. Frankly, we are amazed that advocates for

such perennial problems as logistics support accepted this version of DODI 5000.2. The regulation, as currently published, will allow future program managers to forget many lessons learned at great expense in the past, including the lesson about earth data being pressed here.

What should be on the checklist? We, of course, leave the bulk of the items to the defense acquisition experts. However, we suggest that the item on earth data support specify the following:

> *Mapping, charting, and geodetic (MC&G) support in the form of data base requirements and/or data transformation requirements specifically noting unique data impacts.*

When does the consideration of earth data support for new weapon systems need to begin? The answer is as soon as Milestone 0—Program Initiation/Mission Need Decision has been approved. The consideration of earth data support should be a part of the Concept Exploration/Definition Phase. This early consideration is essential when designing hardware. It is at this point that a contractor can very easily design his system around data and a data format which already exist. If the developer cannot do this, and he genuinely needs a new earth data product, this is also the appropriate time to identify this fact to the earth data producer, the Defense Mapping Agency.

A checklist can force this early consideration of earth data support. The Program Manager will be compelled to examine earth data support during Concept Exploration/Definition if the checklist becomes part of DOD Instruction 5000.2 and earth data support becomes a mandatory consideration for each milestone

review. With a checklist in hand, the Program Manager will have to document earth data support status in the System Concept Paper in preparation for Milestone I.

Add an Earth Data Expert to the DAB

The Defense Acquisition Board (DAB) controls the defense acquisition system. It has the responsibility for ensuring that the provisions of the defense acquisition regulations including DOD Instruction 5000.2 are met. As DODI 5000.2 stands today, the DAB has the power to ensure proper consideration of earth data support for new weapon systems. But the DAB has an enormous number of important issues to consider, and it could easily overlook earth data as the Defense System Acquisition Review Council did in the past.

We offer two recommendations to make the job of the DAB easier with respect to this problem. The first is the addition of the checklist to DODI 5000.2 detailed above. The second recommendation is the addition of an earth data expert to the DAB Operations office. A person with a thorough knowledge of mapping, charting, and geodetic data in an advisory capacity would ensure proper consideration of earth data support.

The earth data expert should serve as an advisory member of DAB acquisition committees. Under the DAB system, the acquisition committee review is the meeting where the substantive discussions take place. The earth data expert should be given an opportunity to review the draft documentation which is required to be submitted three months before the acquisition committee review. This would allow him to submit his written findings relevant to earth data support to the

chairman of the committee before the committee holds it review. The earth data expert should then participate in the acquisition committee review. This placement and utilization of a specialized individual in the Defense Acquisition Board process would go a long way toward precluding the problems of the past.

Not every area of concern that might be included on the proposed checklist in DODI 5000.2 needs an expert to advocate its position to the DAB. Most acquisition professionals already understand the need to consider areas such as maintainability and training. These traditional areas of concern already have advocates in the system.

Earth data is an area which requires an expert for several reasons. It is a technical field requiring a basic education in geodetic science or a related subject. To be an earth data expert, an individual needs extensive experience in the related fields of cartography, geography, geology, oceanography, and astronomy as well as computer science and mathematics. The well-rounded earth data expert would also have some knowledge of soils engineering, forestry, meteorology, and perhaps more. Because the earth data field is so technical and specialized, few people in the acquisition community have enough knowledge to perform the tasks of an earth data expert for the Defense Acquisition Board.

The Defense Mapping Agency logically should supply the needed person to the Defense Acquisition Board Operations office. This is not a radical new idea; DMA has long supplied liaison officers to various Defense organizations. In particular, DMA has arrange-

ments with the Assistant Secretaries for Research and Development (R&D) of the Army, Navy, and Air Force to provide liaison personnel. These people work to help identify earth data requirements in the services' R&D programs. The assignment of a DMA earth data expert to DAB Operations would complement those in the service secretary offices and be beneficial to both the Defense Acquisition Board and the Defense Mapping Agency.

A final note on the Defense Acquisition Board: its members should be made aware of the funding for earth data development and production. When the DAB approves Full Scale Development of a system which requires earth data support, it is giving implicit approval to Defense Mapping Agency to develop the means to produce the required data. Once DMA is authorized to produce a certain data base, it submits its own Program Objective Memorandum to request funding for this data development and production. It does not make sense to approve the production of hardware which requires earth data support without concurrently approving the production of the earth data. The Program Manager is responsible to make sure that the Defense Acquisition Board members understand this. The earth data expert could assist in this task. Since many of the DAB members also serve on the Defense Resources Board which approves the allocation of funds, awareness by the DAB should ensure proper funding for earth data production.

Draft A New Program Decision Memorandum

We recommend that the mapping, charting, and geodetic data provisions of the August 1985 Program

Decision Memorandum (PDM–85) and its implementation plan be rescinded immediately.[3] (Chapter 5 detailed the failings of PDM–85.) We fully recognize that some of the intentions of PDM–85 were achieved. Most notably, PDM–85 raised the level of awareness of the issues associated with earth data support. The expressed provisions of PDM–85 dealing with funding have, however, totally failed.

The military departments rendered PDM–85 useless simply by avoiding compliance with its funding provisions. The Navy readjusted its requirements for gravity data to support Trident II submarine operations rather than pay for the support (*see Chapter 5*). In another major incident, the Defense Mapping Agency refused to honor a request from the Strategic Air Command (SAC) for mapping support for mobile missile studies unless SAC would comply with the PDM–85 directive and pay for the data. SAC resisted this through the Pentagon bureaucracy and prevailed. DMA ultimately produced and paid for the products requested by SAC.[4]

Perhaps the final confrontation was over earth data to support the B–1B Weapon System Trainer (*see Chapter 3*). The Strategic Air Command requested large volumes of high resolution digital earth data. The Defense Mapping Agency pointed out that this was unique data, extremely expensive to produce, and was subject to cost reimbursement. At the height of this controversy, a scientist at DMA devised a lower cost data set which would satisfy SAC's requirement. The uproar over PDM–85 faded away, but nothing changed. The earth data provisions of PDM–85 are still on the books, but no one is any more prepared to program

and transfer funds to the Defense Mapping Agency for mapping, charting, and geodetic data than they ever were.

Rescinding PDM–85 is not enough; it should be replaced with some specific guidance. We suggest, though, that the Deputy Secretary of Defense sign a memorandum immediately rescinding the earth data provisions of PDM–85 and the June 1986 implementation plan. Since the previous funding guidance was issued by a Program Decision Memorandum, it should be replaced by new PDM guidance. The new PDM should state:

(1) All funding for the development and production of mapping, charting, and geodetic data will be contained in the Defense Mapping Agency Program Objective Memorandum;

(2) Communication between a Program Office and the Defense Mapping Agency will begin early in the Concept Exploration/Definition Phase of a new weapon program as soon as it is determined that earth data support will be required; and

(3) The responsibility for this contact is assigned to the Program Manager.

The last item would be greatly facilitated by the addition of a checklist to DOD Instruction 5000.2 as recommended earlier in this chapter. In fact, all of these recommendations are meant to work in concert to establish a better environment for providing new weapons with their required earth data products.

Consolidate Earth Data Requirements

Each of the military departments has an office responsible for handling that department's requirements

for earth data. In the case of the Army, that office is under the Assistant Chief of Staff for Intelligence (ACS/I) in the US Army Headquarters. This office has in the past solicited requirements for earth data from the components of the Army. It then screened and collated all of these requirements and submitted them to the Defense Mapping Agency.

Several years ago, the Army recognized a need for a change in the procedures for handling earth data requirements. Recognizing that additional technical help was needed to fully evaluate and consolidate its mapping, charting, and geodetic (MC&G) data requirements, the Army turned to the logical place, the Engineer Topographic Laboratory (ETL) at Fort Belvoir, Virginia. The Engineer Topographic Laboratory, as its name implies, already had the responsibility for performing research and development in earth data specialties, such as terrain analysis, required to support Army combat forces. ETL responded by forming a new office and staffing it with a sufficient number of scientists and engineers to handle the task of screening and consolidating earth data requirements.

What the Army's change amounted to was adding a step in the earth data requirements process. All of the Army's laboratories and technical development activities must now send their requests for earth data to ETL instead of directly to the MC&G office in the Army Headquarters staff. The Army notified its components of this change in procedures by message and followed by changing the appropriate Army regulations.

The Army achieved a stunning success, if we can use that term in describing the functions of a bureaucracy, in its new ability to consolidate earth data requirements. The ETL determined that over 70 new Army

systems in development could be supported with a single new earth data product which later came to be known as Tactical Terrain Data (TTD). Because of the number of systems which would be supported, the Army was able to show the direct link between this product and the Army's future combat effectiveness. The result was obvious: great significance and priority were given to the development of TTD.

The secret of the Army's success was *commitment* to a good plan. The plan, itself, of adding a technical staff into the requirements flow process was excellent. But the commitment to make it work was truly extraordinary. ETL initially staffed the new office with approximately 20 scientists and engineers, and it did so by a reallocation of personnel and resources. This was a zero sum game, which means that ETL had to give up something to establish a new office with a new function. We salute the Army for its commitment and its success.

There are other facets to this success story—all good. Army personnel were able to work with the Defense Mapping Agency to define the specifications of Tactical Terrain Data in record time. DMA invited the other services to participate in the TTD planning meetings with the Army. The other services learned that they also could use TTD thus expanding its value.

Requirements consolidation, we feel, is one of the big keys to the future of earth data support. DMA will obviously be better able to supply the nation's combat forces with earth data products if the number of products required can be reduced to an absolute minimum. This has already been recognized, and the Army system for handling earth data requirements has become

a model held up to the other military departments to emulate.

We do not want anyone to misunderstand our priorities because of our enthusiasm for the Army's success at consolidating earth data requirements. The root of the earth data problem is with the defense acquisition system and not with the military departments. Requirements consolidation by the military departments alone will not solve the problem. But requirements consolidation is a genuine achievement and will work excellently in concert with our recommended changes in the defense acquisition system as it relates to earth data.

Adopt the Army's System for Handling Earth Data

The other military departments could easily adopt the Army system for handling earth data requirements because they already have the organizational structure to accommodate it. Each has an office with responsibility for screening and forwarding earth data requirements to the Defense Mapping Agency. Also, each has a laboratory which performs earth data research and development to support its own forces. These laboratories, therefore, have the technical expertise to assume the screening and consolidation of earth data requirements.

The Navy is already moving toward establishing a system similar to that of the Army. The office of the Oceanographer of the Navy manages all Navy requirements for earth data support. The Navy laboratory with the expertise is the Naval Ocean Research and Development Activity (NORDA) in Bay Saint Louis, Mississippi. The Navy faces a very difficult task more from

an organizational standpoint than from a technical one. There are four different combat communities: aviation, surface warfare, submarines, and land combat (Marine Corps). The Navy tends to separate its research, development, and acquisition along these community lines. Fortunately, the technical expertise in earth data specialties is consolidated in NORDA. Logically, NORDA should receive all Navy requests for new data before they are submitted to the office of the Oceanographer of the Navy.

The Air Force has both the organizational structure and the need to establish an improved system for handling earth data requirements. The Air Force Intelligence Service (AFIS) has long had an office responsible for handling all mapping, charting, and geodetic (MC&G) data requests. Rome Air Development Center (RADC) on Griffiss Air Force Base, New York, also supports the Air Force with MC&G research and development. The obvious area of need in the Air Force concerns the earth data required to support aircraft training simulators. In the past, each system was developed completely separately by an independent program office utilizing different contractors. The result was that virtually every aircraft simulator required its own unique data set or data in a unique format to function. As a starting point, the Air Force should consolidate the requirements for earth data for all future aircraft simulators into a request for a single product.

In order for the Navy and the Air Force to develop new procedures for handling earth data requirements, these military departments will have to take vigorous action in several areas. They will have to commit the resources, both personnel and dollars, to this task. Like

the Army, they will have to change existing service regulations to support these new procedures. We strongly recommend that the Navy and the Air Force adopt a system for handling earth data requirements to support new weapons similar to the system in place in the Army.

Increase DOD Involvement in Consolidating Earth Data

All of the suggested actions toward consolidation of earth data requirements by the military departments have, at the least, been suggested before; many are either accomplished or in progress. We would like to offer something new. It is time for the Department of Defense to increase its involvement in this area. The department should take the initiative to support and, if necessary, mandate the requirements consolidation process by the military departments.

Earth data needs should be consolidated according to the function that they support and the consolidation process should be elevated to the Department of Defense level. Historically, each individual system had its own support requirements. Even if each military department creates its own central organization for screening earth data requirements, there is still a problem: many functions cut across service lines. For example, it makes good sense to support all tactical aircraft simulators, Air Force and Navy, with a single earth data product. The Department of Defense should mandate and manage this level of requirements consolidation.

The responsibility for consolidating earth data requirements at the DOD level is under the purview of

the DOD MC&G Requirements and Programs Review Group, which exists within the office of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence [ASD(C^3I)]. Currently, the review group meets only "as required." It should meet regularly, perhaps quarterly, specifically for the purpose of reviewing the status of earth data support and consolidation of requirements for new weapon systems. Representatives from the offices in each of the military departments that handle earth data requirements and from the service laboratories that support those offices should always attend and participate in these meetings. The review group should encourage frequent and substantive communications between the meeting participants. When the review group meets formally, it should review the military departments' programs for consolidation opportunities and review the status of earth data requirements consolidation efforts in progress. The DOD MC&G Requirements and Programs Review Group should have the authority to assign a lead service to each consolidation effort.

Our recommendation makes sense for a number of reasons, and the time is right to create a DOD earth data requirements system. The Defense Mapping Agency was formed to eliminate duplication of earth data production, and it should be allowed to do just that. Production efficiency will dramatically improve when the DOD MC&G Requirements and Programs Review Group reduces the number of earth data products required. This can only be accomplished at the highest level within the Department of Defense by the process we have recommended. The budget reductions alone will drive the DOD toward using its considerable

resources more efficiently. Also, our recommendation fits in exactly with the Goldwater-Nichols Department of Defense Reorganization Act of 1986 by stressing the need for "jointness." The potential savings in manpower and money are tremendous; increased sharing of the database will improve intra- and interservice cooperation; and the organizational structures already exist to accomplish our plan. We recommend that the DOD take action immediately to initiate the process of consolidation of requirements for earth data products as well as revising the defense acquisition system as it relates to earth data.

7. FUTURE DATA PRODUCTION

A series of developments and innovative changes in procedure are underway that promise to give hope to the future for the exploding earth data requirements explained earlier. If more attention is devoted to early identification of needs, more can be done to satisfy them. Research is now underway to greatly enhance the ability of the DOD to produce the needed data, and follow-on efforts to make available very large quantities of digital data in near-real-time are showing positive results. Large data bases of digital mapping, charting and geodetic data will be available for users to access and manipulate as required. These advancements will greatly reduce the data standardization problems that the earth data community are now experiencing.

The Army has been a leader in the area of early identification of digital mapping, charting, and geodetic data requirements. In the early 1980s the Army identified a need for data to support over 20 battlefield management and other weapon systems. All these emerging systems required high resolution data with more information than was currently being extracted from standard paper products such as the 1:50,000 scale topographic line map. This enhanced digital

earth data set combined the attributes of several standard products now produced in hard copy form. As discussed in Chapter 3, this data goes far beyond what the foot soldier has traditionally used. Interpreted data about the battlefield environment (soils, slopes, hydrology) is added to the traditional map data and all of this can be manipulated in digital form.

Evolving Digital Technology

The military's growing need for sophisticated digital products, together with the availability of high performance graphics hardware, has led to an ever-expanding set of systems. These systems seek to support the doctrinal emphasis on mobility and fast reaction in the field. The combination of digital intelligence and earth data is essential to combat planning and execution in the future. Intelligence preparation of the battlefield and sensor management are two areas where this data will be required. Mobile graphic display systems will help commanders identify aircraft flight paths, mobility corridors, helicopter landing and drop zones, and river crossings. These interactive systems will also respond to communications planning, sensor positioning, and line of sight problems.

The term Tactical Terrain Data (TTD) was devised by the Defense Mapping Agency to describe the data set developed to support these emerging requirements. This has been a multiservice effort with input from the Air Force and Navy as well as the Army. In the near term, TTD will be used by the Army's Digital Topographic Support System (DTSS). Scheduled for fielding in 1990, the DTSS will be capable of manipulating digital terrain information and generating tactical ter-

rain graphics. In addition, the DTSS will support the All Source Analysis System (ASAS) which will automate the collection and management of numerous intelligence sources. The ASAS will perform order-of-battle analysis, situation evaluation, and critical target analysis functions. Tactical Terrain Data in concert with the DTSS will also be used by the Army's highly successful Firefinder antimortar, antiartillery system.

In his recent article in *Defense 88*, the director of the Defense Mapping Agency, Major General Robert Durkin, cited the cumulative effect of all these new systems. In an 18-month period ending in March 1988, the Air Force alone requested digital high resolution products representing 1,000 man-years of DMA effort. Navy requirements for similar data could potentially match those of the Air Force. The Army's needs may be the greatest of all; the Army's projected requirements for TTD could total over 30,000 man-years of DMA effort.[1] DMA is hoping to simplify these overwhelming requirements with its programs for future data production and distribution.

Defense Mapping Agency Modernization

To respond to the growing demand for digital data the Defense Mapping Agency now has an extensive modernization program underway that will have a positive effect on many of the problems discussed earlier. The modernized production environment will result in a 75 percent decrease in production pipeline time and a 50 percent reduction in production costs.[2]

These efficiencies are achieved by collecting and processing data in an all-digital environment. This process will not change the traditional suite of paper

products that is produced today. However, as the data will be available in digital form, it can be developed into standardized data sets for use by a myriad of systems. Thus, the production of the standard products will also provide data in digital form for use by the emerging systems. These improvements are not a panacea for all problems, but the greater output and reduced costs will help the current situation and will make earth data support for future weapon systems more readily available.

Looking beyond the early 1990s, when the modernized system will be fully operational, we can see a series of initiatives that respond to the thirst for near-real-time information at all levels in the DOD. A distributive data base architecture system concept is the answer to earth data requirements of the future. This will enable world-wide users to have rapid access to earth data in digital form for their immediate use.[3]

This massive data base will take today's analog or hard copy products and capture them in digital form. Current digital products will also be integrated into this system. There will then exist an intelligent representation of object space that can be readily available for human visual interpretation. This concept of do-it-yourself mapping, charting, and geodetic data has unlimited possibilities. Customers can literally design their own products from the raw or basic data. A typical battlefield commander can select a geographic area and bring up a topographic model of that area on a display screen. He can then add cultural features such as lines of communication. Finally, detailed current intelligence data can be overlaid to complete the intelligence

preparation for battle. The possible uses for this type of data manipulation and display are limitless.

The system is also being designed so that the user can add value to the data base. For example, water depths and beach slopes can be added by Marines as they explore potential landing areas. These data, in turn, can be returned to the central depository for use by others and for revising existing products.

Data will be furnished in two distinct architectures. The first is narrow band, electronic, on-line and is somewhat limited in scope and application. Included here are such things as safety notices, change notices, point/target data of great perishability, and crisis support data. Users will be able to access this data through several DOD networks and issue queries to answer specific needs. The second architecture is off-line, with distribution by means of high-volume, low-cost media (such as optical disks) with broad scope and application. Data provided in this form would conform to standards of content, coverage, and format just as the hard copy maps and charts of today do. This data would be updated and provided on a regular basis. Earth data in this form will be deployed to the lowest echelon in the force structure possible to respond to crisis needs and to ensure survivability.

This data base concept is unique and may in itself be an answer to future mushrooming earth data requirements. Users and weapon system developers will be aware of what is universally available to support their systems. System designs will take advantage of the basic data set, and there will be little reason to design a system that uses data that are not contained in

the data base. Enhancements to the data base will be negotiated based on user needs.

The most important aspect of the distributed data base system will be its contribution towards standardization. The problems caused by weapon system developers using unique data types could be drastically reduced. The universally accessible data base will be the standard which everyone uses. Developers will be forced to design data formatting and transformations into their system thereby reducing the burdens on DMA.

Standardization of Earth Data

Recognizing that standardization was the near-term solution to the problem, the Joint Requirements Oversight Council formed a special study group to review military standards for digital mapping, charting, and geodetic data. The study group, chartered in 1986, was composed of general and flag officers from the Army, Navy, Air Force, Marine Corps, and DMA. Representatives from the Joint Chiefs of Staff and the Office of the Secretary of Defense also participated in this effort.

The study group specifically looked at areas where digital earth data could be standardized and recommended mechanisms for the standardization process and means for enforcing these standards in weapon systems development. The group's major findings and conclusions were:

- There are only limited standards that can be applied to earth data. There are no military standards (MILSTANDARDS) now governing digital mapping,

charting, and geodetic data within DOD. The reliance on informal standards causes confusion for developers and contributes to the proliferation of nonstandard data types.

- There is no chartered organization to represent standardization in both national and international forums. This organization should be the Defense Mapping Agency.
- MILSTANDARDS are the logical point at which to start the standardization process. These are required in 11 major areas covering data production, data use and program sustainment. Many of these product and process standards can be generated immediately, resulting in high payback with new weapon system developers.
- DOD must institute a broad range of controls to successfully standardize digital earth data work.[4]

These recommendations are being pursued for potential near-term benefit. The generation of MILSTANDARDS is the first step to institutionalizing and focusing attention on the problem. Weapon system developers are far more likely to deal with formal data standards than with the current informal ones. However, standardization through these formal means is only part of the answer. It must be accompanied with the other changes suggested in Chapter 6.

The fact that the Joint Requirements Oversight Council decided to study this problem is an enormous step in the right direction. The dialogue among the committee members and the general officer steering group surely contributed to greater awareness of data standardization problems. It is through high-level groups such as these that the message will be carried and progress will be made.

8. OUTLOOK

In the previous chapters we have described a series of problems that have plagued weapon system development for many years. The effects of these problems have not received widespread notoriety or media attention. Nevertheless, the effectiveness of our major systems is at stake. Fortunately, the serious implications of not being able to use a weapon where and when we need to have not been a major factor in any recent hostilities. But what if the United States had to use the cruise missile system in an area where digital data does not exist? What if the Navy, using the Trident II system, is called upon to patrol an area where launch-region gravity data is unavailable? The answers to these questions are straightforward: either the system could not be employed at all or, in some cases, serious degradation to accuracy would occur. Neither of these alternatives is acceptable considering the massive cost of system development and the relative small cost of supporting earth data generation.

The proposed solutions to the lack of attention given to early identification of earth data requirements are simple. Institutionalization of the process is the key

to awareness on the part of the users. The establishment of standards for mapping, charting, and geodetic data is the first step in this process. These standards will be the bases around which developers will design their systems.

The suggested modifications to DODI 5000.2 will help formalize the process and bring awareness to the problem. The existence of formal checklists and an earth data expert advisor to the DAB Operations Office will further the solutions to these problems.

Improved intraservice consolidation of requirements is an important step. Following the Army's lead in this area, the other services should work diligently to minimize their requests for unique data by combining requirements for new systems wherever possible.

The more formal exercising of authority on the part of the DOD MC&G Requirements and Programs Review Group is a means to focus the attention of the services towards consolidation of requirements. Tremendous payoffs are possible in this area, particularly in the future years of shrinking budgets.

Replacing the provisions of PDM–85 is also essential in order to respond properly to earth data needs. Experience has shown that the services will not use the PDM–85 mechanisms to acquire their unique earth data; they will avoid them and look for other means to achieve their goals. The results could be disastrous: our forces could face an enemy whose weapons were more effective than ours. Funding for all earth data support, including unique new types of data, should properly be assigned to the Defense Mapping Agency.

The outlook is good and tremendous progress has been made in recent years in solving these problems. Interaction between weapon system developers and DMA has increased with the establishment of liaison positions in the offices of the service secretaries responsible for R&D. A broad spectrum of people in the acquisition community are currently aware of the importance of earth data to new computer-operated or computer-assisted weapons. DOD-level committees, like the Joint Requirements Oversight Committee, are also helping to direct high-level attention to many of the important issues.

The research in which DMA is now actively engaged to develop an all-digital production capability and a distributive data base system will surely help the overall situation. In the early 1990s when this is available, all users will be able to access a standard set of earth data that will be continuously updated. This massive effort will also enable DMA to produce more data at less cost.

The Joint Requirements Oversight Council Special Study Group has also helped to identify standardization issues and generally bring these issues to focus at high levels within the DOD. Standardization is a key element of DMA's Distributed Production Architecture, the program to give the earth data users more direct access to DMA data. Standardization will also support the effort of the services to consolidate earth data requirements by function and not by system.

Significant progress has been made over the last several years in many of these areas. The Defense Mapping Agency has assigned technical people to the offices of the assistant secretaries of the services for

R&D. These people serve as technical advisors and provide the early warning for new systems that could require earth data support.

To tie all of the current efforts together, a comprehensive program is required to assure that our combat forces have modern weapons fully supported with the critical earth data. We are encouraged because so many elements of a comprehensive program are in progress: the DMA modernization program, the program to give users rapid access to DMA data, the move toward standardization of earth data products, and the beginnings of an effective requirements consolidation process.

For the earth data problem to be truly resolved, DOD must make changes in the defense acquisition system. DOD regulations must explicitly instruct Program Managers about earth data considerations. The Defense Acquisition Board needs a full-time earth data advisor. DOD must eliminate the faulty earth data provisions of PDM–85. And the military departments and DOD must complete the requirements consolidation process.

America is renowned for its willingness to change and move forward, particularly in the fields of new technology. Earth data, a seemingly mundane subject, is vital to modern high technology weapons. We are confident that the Department of Defense will move forward and make the changes necessary to assure the earth data support critical to our national defense into the next century.

APPENDICES

APPENDIX A

Definitions of Standard Defense Mapping Agency Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD)

Reprinted, with permission, from Defense Mapping Agency, "Data Information Sheets," October 1988

DATA INFORMATION SHEET

The Defense Mapping Agency - October 1988

DIGITAL TERRAIN ELEVATION DATA (DTED) – LEVEL 1

SUMMARY: A uniform matrix of terrain elevation values. Provides basic quantitative data for all military training, planning, and operating systems that require terrain elevation, slope, and/or surface roughness information.

PRODUCT SPECIFICATION: DMA Product Specifications for Digital Terrain Elevation Data, Second Edition, April 1986 (PS/1CD/200,PS/1CF/200).

DATA DENSITY: The information content is approximately equivalent to the contour information represented on 1:250,000 scale maps. Exploitation at larger scales must consider each individual cell's accuracy evaluation.

COORDINATE REFERENCE SYSTEM: Geographic

DATUM: Horizontal – World Geodetic System (WGS)
Vertical – Mean Sea Level (MSL)

CONTENT: Each cell header record provides identification, administrative data, and information (parameters) required for the application, maintenance, and verification of the elevation values. Each Elevation Data Record contains 1201 elevation values (meters) along a single meridian. A cell will have 201 to 1201 Elevation Data Records depending upon the appropriate latitude zone. Elevations are spaced in accordance with the following table:

Zone	Latitude	Spacing Lat/Long
I	0° – 50° N-S	3 by 3 arc seconds
II	50° – 70° N-S	3 by 6 arc seconds
III	70° – 75° N-S	3 by 9 arc seconds
IV	75° – 80° N-S	3 by 12 arc seconds
V	80° – 90° N-S	3 by 18 arc seconds

STRUCTURE: Matrix

FORMAT: ASCII labeled variable length records. (See product specifications for details.)

MEDIA: 9 track, 1600 or 6250 CPI, 1/2 inch magnetic tape.

APPENDIX A

STANDARD FILE SIZE: 1° by 1° geographic cell identified by its southwest corner coordinates.

ACCURACY:

Accuracy statements are individually calculated for every product and provided in the Accuracy Header Record. Using our best sources, the accuracy evaluations typically are in the following ranges:

Absolute Horizontal	25 to 35 meters at 90 percent circular error
Point-to-Point Horizontal	15 to 30 meters at 90 percent circular error
Absolute Vertical	± 25 to 30 meters at 90 percent linear error
Point-to-Point Vertical	± 20 to 25 meters at 90 percent linear error

DMA Product Specifications accuracy objectives for DTED-1 are:

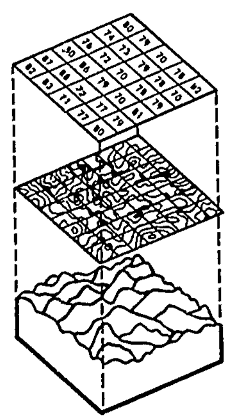
Absolute Horizontal	130 meters at 90 percent circular error
Absolute Vertical	± 30 meters at 90 percent linear error

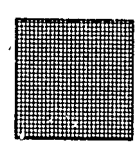
AREA COVERAGE: See DMA Catalog, Part 7 – Digital Data Products, Volume I – Terrain and Feature Data (CATP7V01). This volume is revised semiannually.

APPLICATIONS: DTED initially supported applications modeling the influence of terrain on radar line-of-sight and the appearance of radar return scenes. The success of this concept led to the widespread exploitation of DTED in virtually every type of aircraft flight simulator now in use.

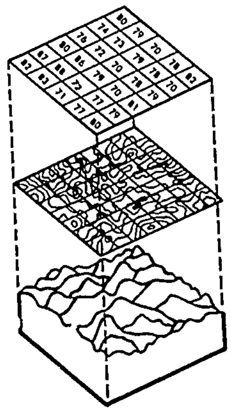
Level 1 DTED are now accepted as the basic medium resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or terrain roughness information in a digital format. Within DMA, these same data can be exploited to support automated map and chart production activities.

DISTRIBUTION POLICY: DISTRIBUTION OF THESE DATA AND CATP7V01 IS LIMITED TO AGENCIES WITHIN THE EXECUTIVE BRANCH OF THE U.S. GOVERNMENT AND QUALIFIED CONTRACTORS.

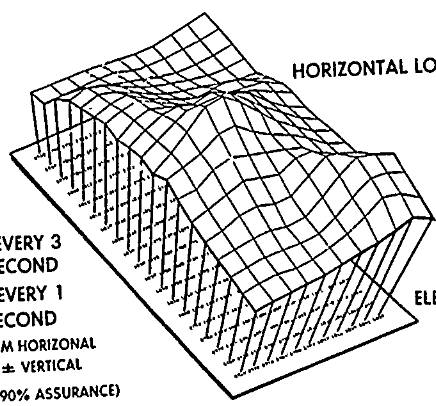




DATA CONTENT	=	ELEVATIONS (METERS) LATITUDE/LONGITUDE
DATA FORMAT	=	MATRIX
DATA FILE	=	1 DEGREE CELL
DATA RECORD	=	ELEVATIONS VALUES S TO N SAME LONGITUDE



DIGITAL TERRAIN DATA



DATA INFORMATION SHEET

The Defense Mapping Agency • October 1988

DIGITAL FEATURE ANALYSIS DATA (DFAD) – LEVEL 1

SUMMARY: A data base consisting of selected natural and man-made planimetric features, type classified as point, line, or area features as a function of their size and composition. Each feature is assigned an identification code and further described (by microcoding) in terms of composition, height, length, and orientation. The data are stored in polygon format and segregated into 1° by 1° geographic cells. Primary applications are radar return simulation, navigation, and terrain obstruction studies.

PRODUCT SPECIFICATION: DMA Product Specifications for Digital Feature Analysis Data (DFAD), Second Edition, April 1986 (PS/1CE/200).

DATA DENSITY: The information content is approximately equivalent to those features found on a 1:250,000 scale map. The typical cell contains 3500 features.

COORDINATE REFERENCE SYSTEM: Geographic

DATUM: Horizontal – World Geodetic System (WGS)
Vertical – Not applicable

CONTENT: The product was developed to provide improved simulation of radar displays. Provides a very generalized representation of the predominant features. The Second Edition Specifications retain all features required by the First Edition and adds lines of communication (roads, railroads, streams, etc.).

STRUCTURE: Vector

FORMAT: Polygon – One data record for each feature. A record contains coded attributes and a coordinate string. (See product specifications for details.)

MEDIA: 9 track, 1600 or 6250 CPI, 1/2 inch magnetic tape.

STANDARD FILE SIZE: 1° by 1° geographic cell identified by its southwest corner coordinates.

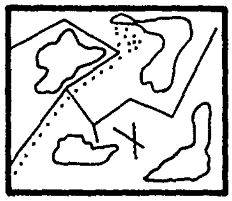
ACCURACY: Accuracy statements are individually calculated for every product. Point-to-point accuracies refer to the relationship of features separated by nominal cell dimensions (approximately 60 nm). Using our best sources, the accuracy evaluations typically are in the following ranges:

Absolute Horizontal	80 to 90 meters at 90 percent circular error
Point-to-Point Horizontal	50 to 60 meters at 90 percent circular error

AREA COVERAGE: See DMA Catalog, Part 7 – Digital Data Products, Volume I – Terrain and Feature Data (CATP7V01). This volume is revised semiannually.

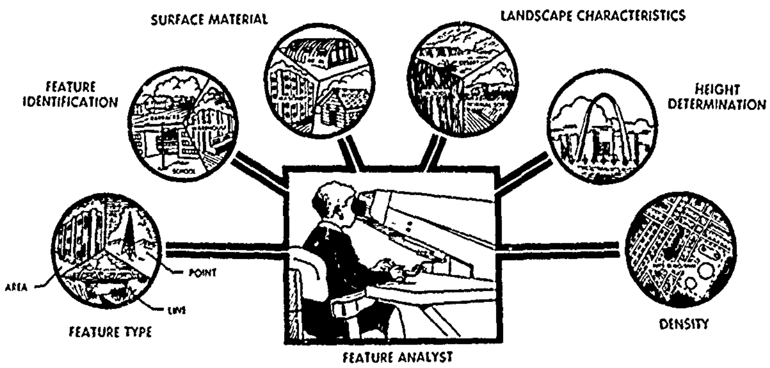
APPLICATIONS: When combined with DTED, provides a digital off-line data base for use by weapon system flight simulators and other types of simulation, such as line of sight, obstruction, and perspective view development. Within DMA, these same data can be exploited to support automated map and chart production activities.

DISTRIBUTION POLICY: DISTRIBUTION OF THESE DATA AND CATP7V01 IS LIMITED TO AGENCIES WITHIN THE EXECUTIVE BRANCH OF THE U.S. GOVERNMENT AND QUALIFIED CONTRACTORS.



DATA CONTENT	=	PLANIMETRIC FEATURES (POINTS, LINES, AREAS)
DATA FORMAT	=	VECTOR
DATA FILE	=	1 DEGREE CELL
DATA RECORD	=	COORDINATES/ATTRIBUTES FOR 1 FEATURE

DESCRIPTIVE DATA



DATA INFORMATION SHEET

The Defense Mapping Agency • October 1988

DIGITAL FEATURE ANALYSIS DATA LEVEL 1C (DFAD 1C)

SUMMARY: Selected natural and man-made planimetric features are type classified as point, line, or area features as a function of their size and composition. Each feature is assigned an identification code and further described (by microcoding) in terms of composition, height, length, and orientation. The data are stored in polygon format and segregated into 1° by 1° geographic cells. Primary applications are radar return simulation and navigation.

PRODUCT SPECIFICATION: DMA Product Specifications for Level 1C Data, First Edition, December 1983 (PS/1CK/100).

DATA DENSITY: Feature density is less than DFAD Level 1 as it is intended to provide a minimum level of operations/capability in those required areas for which DFAD Level 1 cannot be produced within acceptable time limits.

COORDINATE REFERENCE SYSTEM: Geographic

DATUM: Horizontal – World Geodetic System (WGS)
Vertical – Not applicable

CONTENT: The product, produced from cartographic source material, was developed to provide for simulation of radar displays. Provides a very generalized presentation of the predominant features. Most of the software that processes DFAD 1 will also process DFAD 1C. DFAD 1C contains lines of communication (roads, railroads, streams, etc.) similar to DFAD 1, Second Edition.

STRUCTURE: Vector

FORMAT: Polygon – One data record for each feature. The record contains coded attributes and a coordinate string. (See product specifications for details.)

MEDIA: 9 track, 1600 or 6250 CPI, 1/2 inch magnetic tape.

STANDARD FILE SIZE: 1° by 1° geographic cell identified by its southwest corner coordinates.

ACCURACY: Accuracy statements are individually calculated for every product. Point-to-point accuracies refer to the relationship of features separated by nominal cell dimensions. Using our best sources, the accuracy evaluations typically are in the following ranges:

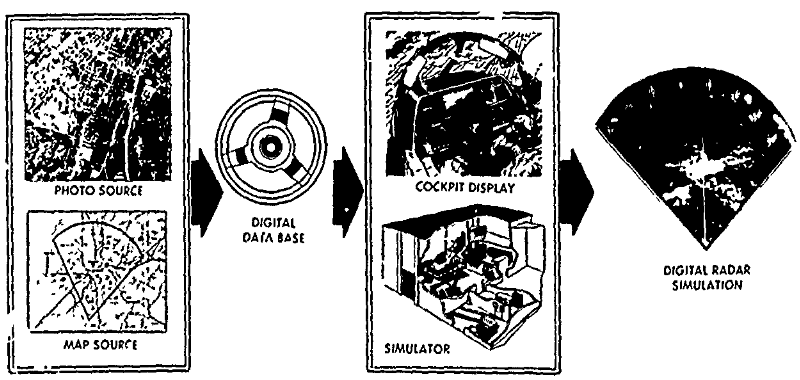
Absolute Horizontal	110 to 120 meters at 90 percent circular error
Point-to-Point Horizontal	155 to 165 meters at 90 percent circular error

AREA COVERAGE: See DMA Catalog, Part 7 – Digital Data Products, Volume I – Terrain and Feature Data (CATP7V01). This volume is revised semiannually.

APPLICATIONS: When combined with DTED, this product supports radar scene simulation in weapon system simulators and navigation.

DISTRIBUTION POLICY: DISTRIBUTION OF THESE DATA AND CATP7V01 IS LIMITED TO AGENCIES WITHIN THE EXECUTIVE BRANCH OF THE U.S. GOVERNMENT AND QUALIFIED CONTRACTORS.

DIGITAL SIMULATION SYSTEM



DATA INFORMATION SHEET

The Defense Mapping Agency - October 1988

DIGITAL FEATURE ANALYSIS DATA LEVEL 2 (DFAD 2)

SUMMARY: DFAD 2 is digitally encoded data describing the physical characteristics of area, line, and point features appearing on the Earth's surface. These characteristics include size, shape, position, orientation, predominant height and surface material type(s). DFAD 2 includes both natural and man-made features.

PRODUCT SPECIFICATION: DMA Product Specifications for Digital Feature Analysis Data (DFAD), Second Edition, April 1986 (PS/1CG/200).

DATA DENSITY: Feature density is roughly equivalent to that of a 1:50,000 scale chart. There are an average of 250 features per 2 by 2 nm patch.

COORDINATE REFERENCE SYSTEM: Geographic

DATUM: Horizontal – World Geodetic System (WGS)
Vertical – Not applicable

CONTENT: This product was developed to provide improved simulation of low altitude radar displays. It provides a detailed set of features existing within each required area. Second Edition Specifications adds lines of communication (roads, railroads, streams, etc.) in the data set. (See product specifications for details.)

STRUCTURE: Vector

FORMAT: Polygon – One data record for each feature. The record contains coded attributes and a coordinate string. (See product specifications for details.)

MEDIA: 9 track, 1600 or 6250 CPI, 1/2 inch magnetic tape.

STANDARD FILE SIZE: Approximately 2 by 2 nm patches, but may vary depending on principal feature of interest.

ACCURACY: Accuracy statements are individually calculated for every product. Point to point accuracies refer to the relationship of features separated by nominal cell dimensions (approximately 60 nm). Using our best sources, the accuracy evaluations typically are in the following ranges:

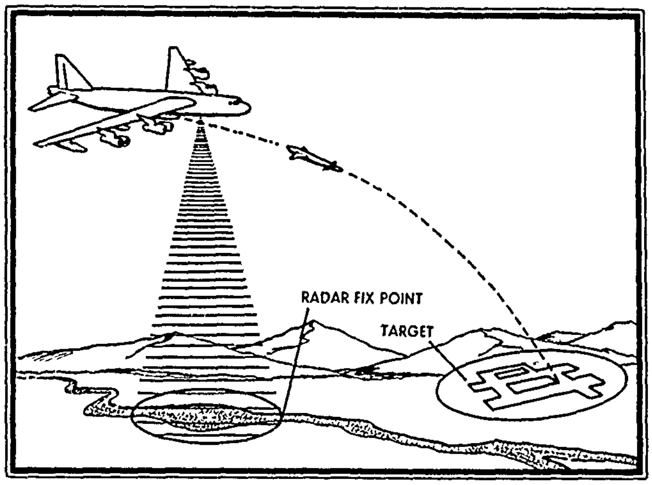
Absolute Horizontal	80 to 90 meters at 90 percent circular error
Point-to-Point Horizontal	50 to 60 meters at 90 percent circular error

AREA COVERAGE: Small areas around points of interest. Location of available areas may be classified. There is no DFAD 2 catalog volume available.

APPLICATIONS: When combined with DTED, provides a detailed digital off-line data base around targets, offset aiming points and radar fix points for use in weapon system simulators.

DISTRIBUTION POLICY: DISTRIBUTION OF THESE DATA IS LIMITED TO AGENCIES WITHIN THE EXECUTIVE BRANCH OF THE U.S. GOVERNMENT AND QUALIFIED CONTRACTORS.

RADAR FIX POINTS



APPENDIX B

Existing Systems/Systems Under Development Requiring Earth Data

<u>Joint Service Systems</u>

AGM-86 Air Launched Cruise Missile (ALCM)
AGM-129 Advanced Cruise Missile (ACM)
Cruise Missile Advanced Guidance (CMAG)
DARPA Image Generation (Side VU)
Joint Automated Terminal Instrument Procedures (AUTO TERPS)
Joint Surveillance Target Attack Radar System
Navstar Global Positioning System (GPS)
Precision Location Strike System (PLSS)
Satellite (Overland) Altimetry
Tactical Reconnaissance Exploitation Demonstration System (TREDS)/TR-1 Ground Station (TRIGS)
Terminal Fix Sensor (TFS)
TR-1 Reconnaissance System
Tomahawk BGM-109A/B/C/D Cruise Missile

<u>Air Force Systems</u>

Advanced Computer Flight Plan (USAFACFP)
Advanced Technology Bomber
AF Rescue Coordination Center Planning System (AFRCCPS)
Automated Combat Mission Folder System (ACMFS)
B-1B
B-52 Weapon Systems Trainer (WST)
C-17
C-130 Weapon System Trainer (WST)
Computer Aided Mission Planning System (CAMPS)
EF-11A Operational Flight Trainer (OFT) System
EF/F/FB-111 Weapon System Trainer (WST)
Enemy Situation Correlation Element (ENSCE)
F-15E Weapons System Trainer (WST)

F-16 Digital Radar Landmass Simulator (DRLMS)
F-16 Improved Digital Radar Landmass Simulator (IDRLMS)
Filmstrips
Integrated Terrain Access and Retrieval System (ITARS)
Minuteman
National Aerospace Plane (NASP)
On Board Electronic Warfare Simulator (OBEWS)
Pave Pillar
PEACEKEEPER
Remote Map Readers (RMR)
Small Intercontinental Ballistic Missile (SICBM)
Survivable Strategic Missile Launcher
Tactical Air Forces (TAF) Small Computer Project
Tactical Re-entry Impacting Munitions (TRIM)

Army Systems

All Source Analysis System (ASAS)
All Source Exploitation In A Combat Environment
Army Training Battlefield Simulation System (ARTBASS)
Battlefield Management System (BMS)
Digital Topographic Support System (DTSS)
Fiber Optics Guided Missile (FOG-M)
Firefinder: AN/TPQ-36 and AN/TPQ-37 Mortar and Artillery Locating Radar
Maneuver Control System (MCS)
Night Navigational and Pilotage System (NNAPS)
PATRIOT Surface to Air Missile System
Pershing II
Position Locating Reporting System (PLRS)
Remotely Monitored Battlefield Sensor (REMBASS)
Remotely Piloted Vehicle (RPV-AQUILA)
Vehicle Integrated Intelligence V(INT)<
Vehicle Navigation Aid System (VNAS)

Navy Systems

A-6E Weapon System Trainer (WST)
AEGIS Air Defense System
AN/BSY-1, FY89 Combat System (formerly SUBACS)
AN/WLQ-4, Sea Nymph
AV-8B Support
Carrier Battle Group (CVBG) Special Chart

E-2C Weapon System Trainer (WST)
EA-6B Weapon System Trainer (WST)
Encapsulated Torpedo (CAPTOR) Mine
Navy Command and Control SystemNavy Optimum Path Aircraft Routing System (OPARS)
Over-the-Horizon-Targeting (OTH-T) Tomahawk and Harpoon Systems
Trident and Trident II

APPENDIX C

Acquisition Management and System Design Principles, Enclosure 2 to Department of Defense Instruction 5000.2, Major System Acquisition Procedures, 19 November 1985. This enclosure functioned as a mandatory checklist of considerations for a Program Manager preparing for a Milestone Review prior to the revision of DODI 5000.2 on 1 September 1987.

Nov 19, 85
5000.2 (Encl 2)

ACQUISITION MANAGEMENT AND
SYSTEM DESIGN PRINCIPLES

The following principles shall be considered in planning major system acquisitions:

1. Mission Analysis
2. Operational Requirements
3. Long Range Planning and Program Stability
4. Affordability
5. Timeliness
6. Acquisition Strategy
7. Participating Activities
8. Industrial Resource Analysis
9. Facility Construction
10. Cost Estimates
11. Goals, Thresholds, and Threshold Ranges, as appropriate
12. International Defense Cooperation
13. Economical Production Rates
14. Test and Evaluation

14. Test and Evaluation
15. Independent Cost Analysis
16. Competition
17. Specification and Standards
18. Standardization and Interoperability in Engineering Design
19. Preplanned Product Improvement
20. Quality
21. System Readiness, Support, and Personnel
22. Reliability and Maintainability
23. Deployment Requirements
24. System Safety
25. Physical Security
26. Nuclear and Chemical Hardness Survivability, and Endurance
27. Producibility and Production Planning
28. Contractor's Production Capability and Contractor Productivity
29. Computer Resources
30. Data Management
31. Metric Units of Measurement
32. Electromagnetic Spectrum and Other Spectrum Allocation
33. Energy Efficiency
34. Environmental Impact
35. Post Production Support
36. Administrative and Business Applications for Automated Information Systems
37. Cost Visibility and Control
38. Evolutionary Development and Acquisition of Command and Control Systems

APPENDIX D

Unclassified Extract Concerning Earth Data from Program Decision Memorandum, Deputy Secretary of Defense William H. Taft IV for the Department of the Army, 22 August 1985, p. 12. The memorandum for the Air Force contained the same paragraph; that for the Navy included additional service-specific instructions.

> Paragraph IX. *Other Decisions*, EH. *Defense Mapping Agency (DMA) Programs.*
> Review ongoing system development programs to identify the need for unique mapping, charting, and geodesy (MC&G) products. Beginning in the FY 1988 POM, fund MC&G activities in the program element for the associated system for later transfer to DMA for execution. Ensure that, as new systems enter full-scale development, the necessary funds for MC&G requirements are identified and programmed.

APPENDIX E

Implementation of August 1985 Program Decision Memorandum for Defense Mapping Agency (DMA) Programs.

This implementation plan was issued by Deputy Secretary of Defense William H. Taft IV on 6 June 1986.

THE DEPUTY SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

6 JUN 1986

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARY OF DEFENSE (R&E)
ASSISTANT SECRETARY OF DEFENSE (A&L)
ASSISTANT SECRETARY OF DEFENSE (C^3I)
ASSISTANT SECRETARY OF DEFENSE (C)
DIRECTOR, DEFENSE MAPPING AGENCY

SUBJECT: Implementation of August 1985 Program Decision Memorandum for Defense Mapping Agency (DMA) Programs

The August 1985 Program Decision Memorandum to the Military Departments and Defense Agencies directed that each Service fund within its TOA the cost of unique mapping, charting, and geodesy (MC&G) operational requirements needed by new systems under development. Resources for production of the required MC&G products will then be transferred when appropriate to DMA for execution.

The enclosed plan was developed to implement this new policy. Key aspects of the plan include a planning methodology for determining MC&G support requirements; establishment of memoranda of agreement between developing Services and DMA; and annual transfers of Service TOA to DMA via program budget decision (PBD). The Director, Defense Mapping Agency, who serves as the Program Manager and coordinator of all DoD MC&G resources and activities, is assigned the leadership role in the execution of this policy. OSD oversight will be administered through the Office of the Assistant Secretary of Defense (C³I).

Because MC&G products are essential to the operation of many modern weapon systems, consideration of MC&G and derivative data affecting targeting and navigation/position determination will now become an additional design principle subject to consideration at system Milestone Reviews. DoD components responsible for preparing each System Concept Paper (SCP) "initial draft" will include a discussion of MC&G requirements and issues affecting system development and subsequent operational deployment. Coordination with DMA will be required.

/s/ WHT
William H. Taft, IV

Enclosure
As Stated 34870
cc:
D,PA&E

IMPLEMENTATION PLAN

AUGUST 1985 PDM DECISION ON

DEFENSE MAPPING AGENCY PROGRAMS

1. The August 1985 PDM decision regarding Defense Mapping Agency programs directed the Services to:

"Review ongoing system development programs to identify the need for unique mapping, charting, and geodesy (MC&G) products. Beginning in the FY 1988 POM, fund MC&G activities in

the program element for the associated system for later transfer to DMA for execution. Ensure that, as new systems enter full-scale development, the necessary funds for MC&G requirements are identified and programmed."

This decision recognized that the Services are in the best position to judge the importance of DMA products to reaching the full potential of the systems they are developing and to set priorities among Service programs requiring DMA support. The users of DMA's products are now responsible for providing funding support for new, unique MC&G products for new systems, thereby encouraging a careful review of requirements. Also, this new policy will encourage early identification of MC&G requirements essential for system development to ensure that the full costs of systems are known when decisions are made to proceed with full-scale development. The process described below, in concert with planned changes to DoDI 5000.2 (Major System Acquisition Procedures), will ensure that MC&G data requirements are included as an integral design principle for emerging systems.

Specifically, the Services are required to fund the marginal costs to DMA for production of system-unique products. The marginal cost (baseline delta) will normally include DMA's production ramp-up costs and full-up production costs for production of a new product required for the deployment of a new system. New or upgraded systems which require an increase in standard DMA product area requirements or require accelerated production will generally be excluded from this process and will be left to compete for existing baseline resources.

2. The level of MC&G support resources required for a new system is a factor in determining the applicability of this implementation plan. Although Enclosure 1 refers to the DSARC system and its milestones, the DSARC "major program" category is not sufficient to assess MC&G significance. Any new system requiring MC&G unique product support exceeding $1M or 30 work-years in any given fiscal year of the FYDP will qualify under this plan. Requirements determined to be below this threshold will compete for DMA's baseline resources in the normal POM process. Systems failing DSARC "major program" but meeting the MC&G significance threshold will substitute corresponding Service milestones.

3. Enclosure 1 shows the PDM implementation process. The model reflects the linkage between system development activities and associated MC&G production. It also illustrates the timing, responsibilities, and relationships of activities which support a sequence of MC&G funding decisions for each qualifying system.

a. Row 1 portrays the acquisition cycle and provides the time line on which to base the remaining activities. The first significant milestone after program initiation is the point at which initial funding is placed in a system R&D program element and submitted in a Service POM. Although the graphic references the Major System DSARC development phases and decision milestones specifically, the concept will apply to all system acquisitions.

b. As a system design concept begins to form, the developing Service will consult with DMA in defining system MC&G information requirements (Row 2). The effectiveness of the entire process revolves around this step. These technical discussions very early in the development cycle will lead to an optimal MC&G product definition. Information from DMA will be valuable to the developer during the conceptual effort and the subsequent System Concept Paper (SCP) preparation. This step will normally yield a formal DMA product specification after Milestone II.

c. Similarly, the developing Service and DMA must consult with JCS as deployment alternatives are considered (Row 3). This consultation will provide a forecasted area requirement associated with initial system fielding as well as an area requirement for completed operational deployment. These data in combination with information on the new system's unit acquisition rate and delivery schedule will yield an MC&G data requirement profile. DMA will develop a production schedule satisfactory to the developing Service based on this profile.

Force planning must be considered as the deployment role of each new system is assessed. If a new system is a functional replacement or affects force structure, the associated MC&G requirement may supplant earlier requirements, reducing the net marginal cost to DMA, thus reducing funding requirements levied on the developing Service.

d. DMA will compute the cost to DMA of satisfying the MC&G support requirement (Row 4). All applicable elements of expense will be included. Items to be considered are ramp-up costs such as hiring and training of new personnel, site preparation, equipment procurement, and fixed plant investment as well as O&M costs for maintenance of a full production posture. DMA will also identify any liquidation costs that may be incurred by a subsequent DSARC decision cancelling the program. If marginal costs in these categories are specifically assessable as system unique in application, they will be a funding responsibility of the developing Service. General purpose items (e.g., S&T mainframe computers)

will be funded by DMA and excluded from consideration in this process.

e. Row 5 represents the OASD(C^3I) role as the action office for OSD oversight in MC&G matters. As a part of this role, the ASD(C^3I) will ensure that proper consideration is given to MC&G topics during the DSARC process. The DoD MC&G Requirements and Programs Review Group will serve as a forum in which DMA, the Service, JCS, and other OSD offices can provide recommendations and other input to ASD(C^3I). ASD(C^3I) will advise the Secretary on issues related to assessment of MC&G significance, cross-Service implications, product commonality and interoperability, and appropriate funding levels.

f. Row 6 illustrates the funding procedures associated with activities previously discussed. DMA will supply the initial MC&G support cost estimate to the developing Service and to ASD(C^3I). When agreement is reached on the appropriate level of MC&G support, the Service will program the MC&G support funding wedge (generally O&M) and associate that funding with the system development program element in all budget exhibits.

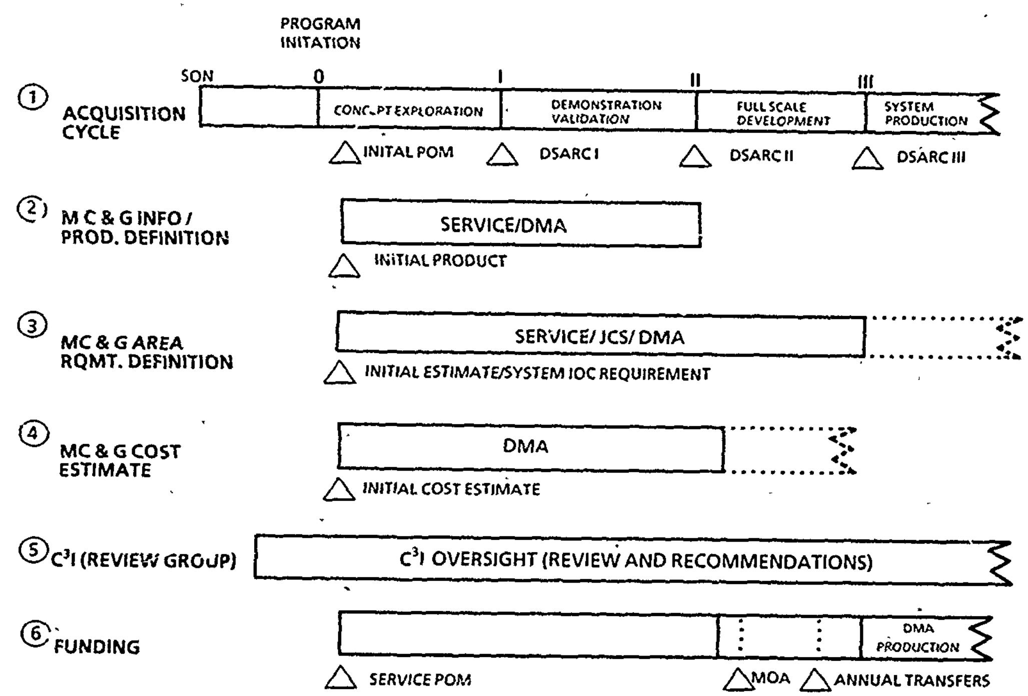
After Milestone II (at the on-set of full-scale development), DMA will draft a Memorandum of Agreement (MOA) documenting results of their MC&G support negotiations with the developing Service. The signature of the ASD(C^3I) will reflect OSD approval of the provisions of the MOA. The implementing signatories will be the Director, DMA, and the affected Service Secretary.

The MOA will discuss required product types, total area requirement estimates, and DMA's projected delivery rates. Also included will be a Service commitment to protect the negotiated funding profile during Service POM development. MOAs can be renegotiated subject to ASD(C^3I) approval.

At the point when DMA's production start-up activities must begin (nominally between Milestones II and III), ASD(C) will begin a series of annual TOA transfers to DMA via PBD (as reflected in the MOA). This process will continue annually until provisions of the MOA are satisfied or the MOA is terminated due to program cancellation.

Enclosure
As Stated

PDM IMPLEMENTATION MODEL



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ABBREVIATIONS

ACS/I	Assistant Chief of Staff for Intelligence
AFIS	Air Force Intelligence Service
ALCM	Air Launched Cruise Missile
ASAS	All Source Analysis System
ASD(C^3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
DAB	Defense Acquisition Board
DAE	Defense Acquisition Executive
DAFIF	Digital Aeronautical Flight Information File
DBDB	Digital Bathymetric Data Base
DCP	Decision Coordinating Papers
DFAD	Digital Feature Analysis Data
DMA	Defense Mapping Agency
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
DSARC	Defense System Acquisition Review Council
DSARC II	Defense System Acquisition Review Council, Milestone II
DTED	Digital Terrain Elevation Data
DTSS	Digital Topographic Support System
ETL	Engineer Topographic Laboratory
GLCM	Ground Launched Cruise Missile
ICBM	Intercontinental Ballistic Missile
IOC	Initial Operational Capability
JCMPO	Joint Cruise Missile Program Office
JRMB	Joint Requirements and Management Board
JROC	Joint Requirements Oversight Council
MC&G	Mapping, Charting, and Geodetic data
MILSTANDARDS	Military Standards
MNS	Mission Need Statements
NORDA	Naval Ocean Research and Development Activity
PDM	Program Decision Memorandum
PEO	Program Executive Officer
PPDB	Point Positioning Data Base
RADC	Rome Air Development Center
SAC	Strategic Air Command

SAE	Service Acquisition Executive
SCP	System Concept Papers
SIOP	Single Integrated Operations Plan
SLBM	Sea Launched Ballistic Missile
SLCM	Sea Launched Cruise Missile
TERCOM	Terrain Contour Matching data base
TTD	Tactical Terrain Data
USDRE	Under Secretary of Defense for Research and Engineering
VOD	Vertical Obstruction Data
WMED	World Mean Elevation Data
WST	Weapon System Trainer

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Earth Data
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